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PROCEEDINGS

OF THE

ARCTIC TRANSPORTATION CONFERENCE

YELLOWKNIFE, N.W.T.

DECEMBER 8 & 9, 1970

SPONSORED

BY THE

MINISTRY OF TRANSPORT

AND THE

DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT

VOLUME - 2

(English Version)

CONFERENCE CO-CHAIRMEN: Hon. Jean Chrétien, P.C., M.P.

Hon. Don Jamieson, P.C., M.P.

Ottawa, Ontario
published February 1, 1971.

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Thirty-four background papers were prepared to provide a body of information and reference material in advance of the discussions at the 1970 Arctic Transportation Conference in Yellowknife NWT, December 8 & 9 1970. This collection of papers as well as other papers presented at the conference are published in volumes 2 and 3 of the proceedings.

Volume 1 contains the proceedings of the opening, second and the final plenary sessions. Volume 1 also contains the speeches at the Conference banquet, a short summary of all papers presented, biographicial sketches of panel members, a list of delegates and discussions at all sessions. Generally speaking, discussion is reported verbatim but in several instances there have been minor alterations and deletions for the sake of brevity and clarity and because of recording difficulties. Papers given by government employees did not represent official policy but were prepared to further discussion of different courses of planning and action.

FOREWORD

THE THEME:

"ARCTIC TRANSPORT IN THE 1970's"

Transportation plays a crucial role in the development of a country. The building of the CPR helped unite Canada. What this generation does in the Arctic can have equally important and long-lasting results. Our objective is a transportation system that contributes to the orderly social and economic development of the area, compatible with the protection of the environment.

The many agencies, commercial interests and general users of transportation services will have a major part to play in helping achieve this objective. Previously, these interested parties had little opportunity for coordinated discussion of their problems. The Arctic Transportation Conference in Yellowknife December 8 and 9, 1970 was held to provide this opportunity.

In presenting this record of the Yellowknife Conference, the Ministry of Transport and the Department of Indian Affairs and Northern Development wish to express their joint appreciation of the work contributed by all concerned.

TABLE OF CONTENTS

NOTE: This table contains the complete list of contents for all three volumes of the Arctic Transportation Conference Proceedings.

	Page
Cover Page	i-ii
Foreword	iii
Table of Contents	V - X

VOLUME 1

SECTION 1 -	GENERAL OPENING SESSION	1
	Address of Welcome - S. M. Hodgson	3
	Address By - Hon. Jean Chrétien	5
SECTION 2 -	TRANSPORTATION AND THE ARCTIC COMMUNITY	15
	Chairman's Opening Address - Robert J. Orange	17
	Address By - James Smith	23
	Address By - A. Okpik	31
	Address By - R. Anderson	35
	Session Discussion	37
SECTION 3 -	PANEL DISCUSSIONS AND SUMMARIES OF PAPERS PRESENTED	55
	Session 3A - Meteorological Services, Air Navigation Aids and Airport Facilities	57
	Session 3B - Eastern Marine Resupply (Including Heavy Helicopter Operations)	73
	Session 4A - Northern Roads, Trucking and Off-Road Transportation	93
	Session 4B - Western Water Transportation (Including Effects of Building a Mackenzie Valley Pipeline)	113

TABLE OF CONTENTS

VOLUME 1 (cont'd.)

		Page
	Session 5A - Ice Information, Marine Navigation Aids and Terminal Facilities	137
	Session 5B - Transportation: People and The Environment	159
	Session 6A - Transportation Facility Costs and User Charges	185
	Session 6B - Northern Railroads and Solids Pipelines	199
	Session 7A - Maritime Bulk Shipping and Ice-Breaker Support	217
	Session 7B - Air Carrier Operations	237
SECTION 4 -	PLENARY SESSION	249
	Opening Remarks By Hon. Jean Chrétien	251
	Summaries By Panel Chairmen	251
	Discussion	268
SECTION 5 -	CLOSING BANQUET	275
	Address By - Hon. Jean Chrétien	277
	Address By - Hon. Don Jamieson	281
APPENDICES		
	Appendix "A" Biographical Sketches of Panelists	309
	Appendix "B" List of Conference Attendees and Contributors	337

VOLUME 2

SECTION 1 -	METEOROLOGICAL SERVICES, AIR NAVIGATION AIDS AND AIRPORT FACILITIES	1
	Air Navigation Facilities - G. E. McDowell	3
	Arctic Airports - M. Baribeau	29

TABLE OF CONTENTS

VOLUME 2 (cont'd.)

		Page
	Meteorological Services in the Arctic - F. W. Benum	45
	Air Transportation In The High Arctic - W. W. Phipps	63
	Arctic Aviation Facilities - Gordon L. Bartsch	71
SECTION 2 -	EASTERN MARINE RE-SUPPLY (INCLUDING HEAVY HELICOPTER OPERATIONS)	85
	East Arctic Marine Resupply - A. H. G. Storrs	87
	Re-Supply - A Review - R. Currie	113
	Eastern Arctic Transportation By Sea In The 1970's - B. N. Malott	127
	Resupply In the Seventies - P. M. Crosbie	139
	The Use of Heavy-Lift Helicopters in Eastern Marine Resupply - J. W. Strath	143
SECTION 3 -	NORTHERN ROADS, TRUCKING AND OFF-ROAD TRANSPORTATION	149
	Northern Road Program - H. W. Woodward	151
	Off Road Trucking Winter Operations - J. Denison	181
	Yukon Roads - K. Baker	189
	Off-Road Vehicles - T. A. Harwood	197
	Air Cushion Vehicles - T. A. Harwood	221
	Off-Road Vehicles - Environmental Design Considerations - N. Carpentier	229
SECTION 4 -	WESTERN WATER TRANSPORTATION (INCLUDING EFFECTS OF BUILDING A MACKENZIE VALLEY PIPELINE	235
	Water Transport on the Mackenzie River System and the Western Arctic - L. R. Montpetit	237

TABLE OF CONTENTS

VOLUME 2 (cont'd.)

		Page
	Current Outlook for Pipelines Out of The Arctic - B. Willson	257
	Current Developments in the Design of Tug/ Barge Transport for the Mackenzie River - R. F. Allan	273
	The Role of the Mackenzie Waterway In Oil Exploration - J. C. Underhill	297
SECTION 5 -	ICE INFORMATION, MARINE NAVIGATION AIDS AND TERMINAL FACILITIES	307
	Marine Navigation Aids and Terminal Aids - J. N. Ballinger	309
	Ice Information Services in the Arctic - F. W. Benum	335
	Terminal Facilities in the Arctic - L. G. Pathy and J. D. Garvie	355
	Ice Information, Marine Navigation, Aids And Terminal Facilities - O.C.S. Robertson	363

VOLUME 3

SECTION 1 -	TRANSPORTATION: PEOPLE AND THE ENVIRONMENT	1
	Transportation People and the Environment A Legislative Base - J. K. Naysmith	3
	Transportation People and the Environment - R. A. Hemstock	13
	The Social and Economic Impact of Transportation - A. Stevenson	19
	Transportation and the Ecology - W. A. Fuller	37
SECTION 2	TRANSPORTATION FACILITY COSTS AND USER CHARGES	47
	Transportation Facility Costs and Charges - I. C. Cornblat	49
	The Feasibility of Facility User Charges In Northern Transportation - E. T. Haefele	87

TABLE OF CONTENTS
VOLUME 3 (cont'd)

		Page
	Transportation Facility Costs and User Charges - K. Wyman	97
	Some Thoughts on User Charge Policy for Northern Transportation - P. Detmold	111
SECTION 3 -	NORTHERN RAILROADS AND SOLIDS PIPELINES	121
	Railroads and Solids Pipeline Transportation In the Canadian North - W. W. Collins	123
	Notes on Intermodal Transportation - A. F. Joplin	131
	Notes on Slurry Pipelines - A. F. Joplin	133
	Notes on Railway Development - A. F. Joplin	137
	Integrated Transportation in the Yukon - R. R. Latimer	143
	Development of Transportation in the Yukon - M. P. Taylor	151
	Railway Construction Down North - V. R. Cox	159
SECTION 4 -	MARITIME BULK SHIPPING AND ICE-BREAKER SUPPORT	163
	Arctic Bulk Shipping - J. D. Leitch	165
	Bulk Shipping and Ice-breaker Support In The Arctic - J. G. German	175
	Maritime Bulk Shipping and Ice-breaker Support - R. S. Grout	207
	Maritime Bulk Shipping and Ice-breaker Support - D. M. Ripley	223
SECTION 5 -	AIR CARRIER OPERATIONS	257
	Air Transport In the Canadian North - J. Courtney	259
	Air Transport in Northern Canada - K. Peiffer	283
	Policy Aspects of Northern Transportation and Facilities - R. A. Morrison	313

TABLE OF CONTENTS
VOLUME 3 (cont'd.)

		Page
	Air Transport In the Canadian North - Max Ward	325
	Developing New Transport Grid In the North - R. P. Engle	329
SECTION 6 -	OTHER PAPERS	335
	Alternatives Open to the Government of Canada - T. G. How	337
	Electronic Guidance Is Not the Complete Answer - J. Moar	351
	Arctic Transportation - J. Moar	355
	Air Transport 70 Status and Requirements - Government of the Northwest Territories	359

VOLUME 2

SECTION 1 - METEOROLOGICAL SERVICES, AIR NAVIGATION AIDS AND AIRPORT FACILITIES

CHAIRMAN: R. P. Engle

PANELISTS: G. E. McDowell

M. Baribeau

F. W. Benum

W. W. Phipps

G. L. Dartsch

"The winds and the waves are always on the side of the alert navigators".

Edward Gibbon.

AIR NAVIGATION FACILITIES

BY: G.E. McDOWELL, REGIONAL DIRECTOR
AIR SERVICES, EDMONTON
& R. S. NOWLAN M.O.T. OTTAWA

Prior to the late 1930's, air navigation in the Arctic was almost entirely by visual reference to the ground. In 1938, Civil Aviation authorities in Ottawa decided to extend air mail service to the Yukon and down the Mackenzie River to the Arctic Coast. This initiated development of what ultimately became the Mackenzie and Northwest staging routes. Later during the war years, electronic NAVAIDS were installed in the central and eastern Arctic in support of "short-hop" routes to Europe. More military NAVAIDS appeared in the 1950's as a result of the DEW line. The majority of these facilities have since been phased out by the military and turned over to civil authorities. They form the backbone of our existing navigational aid system in the Arctic.

It has been said that installation of navigation facilities has not kept pace with the technological developments in aircraft. To a great extent, this is true in that the navigation systems now in use are basically those that were originated prior to or during the war. However, there have been great technological advances in the area of navigation systems, but these advances in technology must always be considered in terms of cost of installation, maintenance and cost of user equipment. In considering major or world-wide navigation systems, international acceptance can be a lengthy process.

The Ministry of Transport has already invested nearly 16 million dollars in Arctic NAVAIDS and spends four million annually in direct operating costs for these

facilities. With the recent increased emphasis on sovereignty and resource development in the Arctic, it is likely that this investment will continue growing. It is hoped that discussions at the Arctic Transportation Conference will help ensure that this growth benefits users to the maximum extent possible.

II THE EXISTING CANADIAN ARCTIC NAVAID SYSTEM

GENERAL

Navigation in the Arctic, as elsewhere, can be conducted on instruments (IFR) or by visual reference to the ground (VFR). Most long range traffic operates IFR while short range traffic is primarily VFR.

To assist the Arctic IFR pilot, there is a network of some 80 ground based electronic NAVAIDS. In addition, larger aircraft are often equipped with extra airborne equipment such as doppler, inertial guidance systems, radar and a sextant. Their main problem is usually the lack of precision approach aids at destination rather than enroute navigation.

A high percentage of Arctic flights operate primarily by visual navigation (VFR). Existing electronic NAVAIDS can be used to some extent on VFR flights but for the most part such flights are to locations without such facilities and charts or personal knowledge of the terrain are the only aids.

Communications, flight safety and at a few busy locations, Air Traffic Control are also factors of

direct concern to both IFR and VFR pilots in the North and these items will be covered later in this paper.

ELECTRONIC NAVIGATIONAL AIDS

The following is a brief description of land based systems that are currently in use internationally together with a rough estimate as to capital cost and their advantages or disadvantages.

- ENROUTE AIDS

LOW FREQUENCY RADIO RANGE (LFR)

LFR's operate in the frequency range of 200-400 KHz with an effective range of 100 miles. These facilities were widely used as air navigation systems, with approximately 25 still operating in Canada. They are being progressively converted to non-directional beacons or phased out if other navigational aids are providing coverage in the area.

Costs - Initially, LFR station costs were in the $100,000 - $150,000 range assuming a road and hydro-electric power to be available at the site.

Operation & Maintenance -
Annual costs including staff and flight checking would be approximately $46,000. If diesel generators are required, operating costs would be increased by $15 - $20,000 per year.

Advantages -

a) Provides both enroute positive track guidance and instrument approach capability.

b) Can be used as a non-directional beacon (NDB) by aircraft equipped with radio compass direction finders (ADF).

c) Can be used by all aircraft equipped with a simple LF receiver.

Disadvantages -

a) Subject to static and interference during adverse weather conditions when needed most.

b) Now obsolete with spare parts in short supply.

c) High maintenance costs.

d) Requires annual retune and flight checks at least twice a year.

NON-DIRECTIONAL RADIO BEACON (NDB)

NDBs are non-directional radio beacons that operate between 200 and 1750 KHz. They are used extensively throughout the world as an enroute aid and can also be used as an approach aid or as a "marker" for Air Traffic Control and in association with other approach aids.

Costs - Long range NDBs cost from $35 - 90,000 and short range facilities from $20 - 60,000 (including costs for access roads and commercial power but excluding MOT generated power or staff accommodation).

Operation & Maintenance -

Direct operating costs for the beacon are minimal, usually under $1200 annually. If diesel generators are used for power, these costs would be additional.

Advantages -

a) Provides both enroute guidance and instrument approach capability.
b) Can be used by all aircraft equipped with ADF.
c) High reliability at low cost.
d) Can operate unattended.
e) Simplicity of equipment coupled with the effective service provided, ensures continued acceptance of this facility.

Disadvantages -

a) Frequency congestion.
b) Subject to static, interference and night effect at extreme ranges.
c) Does not provide positive track guidance.

VHF OMNIDIRECTIONAL RADIO RANGE (VOR)

The VOR operates in the static-free VHF band 108 to 118 megacycles. Each station provides multiple inbound and outbound courses. Signal information to the pilot is visual and provides positive track guidance. Effective range is 100 miles at 10 thousand feet altitude and range increases with height. VOR stations are normally located about 100 miles apart.

Costs - A VOR station costs in the $75 - 150,000 range depending on location. This can increase to as much as $250,000 in difficult terrain.

Operations & Maintenance -

Annual O & M is high and varies with location. Retunes and flight checks at least every six months are required.

Advantages -

a) Has multi course capability.
b) Static free reception.
c) Visual display to pilot.
d) Light weight, low cost airborne receivers available.
e) Can be used as an approach aid.

Disadvantages -

a) Siting of ground installation can be critical and costly because of vulnerability to reflection interference from buildings, power lines, terrain etc.
b) Requires regular flight checks and periodic retunes.
c) Many aircraft operating in North not equipped with VOR receivers.

TACTICAL AIR NAVIGATION UHF OMNI RANGE (TACAN)

TACAN is a military system operating in the UHF band 960 - 1215 MHz. It combines the function of the civil VOR and DME (distance measuring equipment) thus providing the pilot with bearing and distance information to or from the station. TACAN receivers can also utilize combined VOR-TACAN installations (VORTAC).

VOR AND TACAN COMBINATION (VORTAC)

VORTAC is a combination of the civil VOR and the military TACAN into one unified system useable by both military and civil air traffic.

Advantages -

a) Provides pilot with bearing, positive track guidance and distance information.
b) Visual readout of position.
c) Reduces pilot workload.
d) Can be used as an approach aid.

Disadvantages -

a) High capital and operating cost.
b) Requires special airborne equipment.
c) Siting of ground installation can be critical and costly.

VOR WITH DISTANCE MEASURING EQUIPMENT (VOR/DME)

VOR/DME is a VOR with "DISTANCE MEASURING EQUIPMENT" added. The DME ground equipment transmits information when it is interrogated by the aircraft, and actuates a mileage meter on the pilot's instrument panel telling him his distance from the station.

ADVANTAGES AND DISADVANTAGES same as VORTAC.

LONG RANGE NAVIGATION SYSTEM (LORAN)

LORAN A is a hyperbolic system using pulse envelopes at 1.7-2.0 MHz with a base line of about 300 miles and a useable range of several hundred miles. LORAN C is

a hyperbolic system using coherent pulses in the 90-110 KHz band, with a base line of about 500 miles and a useable range of over 1,000 miles.

The pulses from the ground stations are picked up by the receiver (either airborne or marine) and the time difference between pulses from a pair of stations is measured.

LORAN A accuracy is 1/4 - 5 miles depending on geometry and atmospheric conditions. LORAN C accuracy is generally taken to be 1 foot/mile from the master station.

Advantages -

a) Considerable existing coverage.
b) Area navigation capability.
c) New airborne equipment being developed which can be used as an approach aid as well.

Disadvantages -

a) High cost of ground stations.
b) Special airborne equipment required.
c) Readout must be plotted except on very costly airborne installations.
d) Coverage generally limited to sea coast and oceanic areas.

DECCA NAVIGATION SYSTEM (DECCA)

The DECCA navigator is a highly accurate system which provides "position" information to the pilot in several ways depending upon the price of the equipment. Range is about 250 nautical miles. Ground installation

consists of a four transmitter chain, a master with three slave stations. It is a hyperbolic system but uses continuous low frequency waves instead of pulses as in LORAN. Phase synchronized master and slave transmissions create a pattern of constant phase (hyperbolic) position lines between each MASTER and SLAVE pair, the intersection of two hyperbolae being a "fix".

In the air, the usual display is a moving pen, on a rotating chart giving continuous, accurate position information without need for additional mathematics on the part of the pilot

Costs - To establish a DECCA system to cover the Northwest Passage it has been estimated that eleven stations would be required at an estimated cost of $13 million.

Advantages -

a) Accurate visual readout.
b) Suitable for "Area" navigation.

Disadvantages -

a) High cost for both ground installation and airborne equipment.
b) Suitable for use by only a small segment of aircraft operating in the Arctic.
c) Maintenance and operating costs are high.
d) Poor night time coverage.

OMEGA NAVIGATION SYSTEM (OMEGA)

The OMEGA navigation system operates in the Very Low Frequency (VLF) portion of the spectrum (10-14 KHz) within the internationally allocated navigation band.

Each pair of stations provides the navigator with a family of hyperbolic lines of position (LOP's) and eight stations sited with 5-6,000 mile base lines will provide world-wide coverage. Full coverage is expected by late 1972.

Four stations are transmitting on a quasi-operational basis at this time. The four stations are not at full power and the station in New York State is being relocated in North Dakota, tentively scheduled for operational status in October, 1971.

The four stations provide coverage of most of the Western Hemisphere, with signal levels low in the area shielded by the Greenland ice cap. The low signal output from the station in New York State combined with the shielding effect of Greenland, results in low accuracy navigation information in the low latitude areas of the Arctic. (Latitude of Churchill — Resolute). Full power transmitters will drastically improve the accuracy of OMEGA in these areas.

Extensive testing and evaluation has been carried out in all parts of the Arctic and Northern Canada by personnel of MOT, in conjunction with other Canadian Government Departments and U.S. agencies. A long term monitoring programme, in co-operation with the FAA and U.S. Navy is presently underway. The objective is to improve the OMEGA navigation accuracy in these areas. Tests have been carried out on ice breakers and on aircraft, including operations to the North Pole and beyond.

The results have been impressive and indicate that errors of 1-2 miles can be expected over most of the Arctic, when using the computed sky-wave correction tables.

In the Differential Omega mode, accuracies of approximately 1/4 mile for a 40 mile radius around a ground receiver near Washington have already been recorded. This figure is expected to improve with the full power transmitters and the use of new digital filtering receivers.

Costs - Arctic coverage is already available with accuracy within 2-3 miles. For higher accuracy in local areas, "Differential Omega" will be capable of providing accuracy of 1/4 mile for a radius of 40 miles around a ground receiver. The additional receivers at 10 sites that already are equipped with VHF communications would cost $150,000.

Advantages -

a) Arctic coverage from existing ground stations is available and will improve.
b) Airborne equipment will cost from $2,000 to $60,000 depending on amount of automation.
c) Provides "area navigation" capability.
d) Permits "pre-plotting" of route.
e) High reliability in all weather conditions.

Disadvantages -

a) Airborne receiver filter constants must be specified for particular aircraft speed range.
b) The less expensive equipments are manual operation.
c) Antenna requirements for aircraft are severe.

- LANDING AIDS

PRECISION APPROACHES

INSTRUMENT LANDING SYSTEM (ILS)

The ILS provides guidance for approach and landing by means of visual reference to instruments, or by means of airborne auto-land equipment.

The ILS system consists of two radio projections transmitted from the runway. One is the LOCALIZER, with the transmitter located at the far end of the landing runway, projecting a signal down the runway to enable the pilot to line up his approach. The other is the GLIDE PATH, a projection shaped like a platter standing on edge, which enables the pilot to establish his aircraft on the proper descent path to the touchdown point on the runway.

Information is provided visually to the pilot via an instrument with two cross pointers, one horizontal which shows the position of the GLIDE PATH, and the vertical pointer shows which way to turn to line up with the runway.

A complete ILS system comprises several other elements including MARKER BEACONS which tell the pilot his distance from the runway.

Costs - Costs vary considerably with individual sites. ILS systems generally cost in the vicinity of $75,000 to $200,000 plus additional items required in support of an ILS to enable the pilot to carry out a landing in bad visibility including:

		$200,000
Approach lighting system High Intensity	$100,000 +	
Runway lighting system High Intensity	$ 50,000 +	
Ground check equipment	$ 18,000	
Calibration equipment	$ 40,000	
		$158,000
		$358,000

Operations & Maintenance -

Average annual costs are about $22,000 but would be much higher at remote locations.

Advantages -

a) Provides precision guidance in two dimensions.
b) Visual presentation to pilot.
c) Enables all weather operations.

Disadvantages -

a) Siting of ground equipment is critical because of vulnerability to reflection interference.
b) Requires minimum of three flight checks annually.
c) Requires careful monitoring and more attention than other NAVAIDS.

PRECISION APPROACH RADAR (PAR) AND GROUND CONTROLLED APPROACH (GCA)

These are systems whereby a pilot is guided verbally by a controller on the ground using radar equipment. The ground operator can see the aircraft on his

scanning screens which provide azimuth, range and altitude information. No special equipment is required in the aircraft.

PAR is the civil precision approach radar facility.

GCA is a military and civil facility which provides surveillance coverage in addition to having precision approach capability.

QUAD Radar is a military GCA which has precision approach capability on more than one runway. It also can provide surveillance coverage including control of aircraft on the ground. As it can perform just one of these functions at a time, it is suitable only for handling low density traffic. Also, this facility is now considered obsolete and is being phased out by the military. Replacement parts are in short supply.

Costs - Capital cost varies with site but averages $300,000 for PAR. A full GCA facility would cost 2 - 3 times as much.

Operations & Maintenance -

Including operators and flight checking, annual costs would be in excess of $50,000. (Staff accommodation would be extra.)

Advantages -

a) Provides precision approach capability.
b) No special airborne equipment required.
c) Can be used by all radio equipped aircraft and can assist inexperienced or lost pilots.

Disadvantages -

a) High capital and operating costs.
b) Ground controllers must have sufficient traffic to maintain proficiency.
c) Requires skilled maintenance and flight checks.

NON PRECISION APPROACHES

OR

CLOUD BREAKING PROCEDURES

LFR, NDB, VOR, TACAN, VORTAC and VOR/DME can all be used as non-precision approach aids as well as for enroute navigation.

The Arctic system (See Appendix A) consists primarily of NDBs along with a few LFRs and military TACANs. Four of the major airports also have instrument landing systems. The main difference between the navigation system in northern and southern Canada is VOR. No VORs have been installed in the Arctic to date for a variety of reasons - high initial and operating costs, low potential utilization and technical difficulties to name a few. Also, many of the aircraft operating in the Arctic are not equipped to use VOR while virtually all can use LFRs or NDBs.

The criteria which determine the requirement and priority for establishing electronic navigational aids varies somewhat in relation to the basic function the aid is intended to perform. The basic functions are to assist enroute navigation, to serve as terminal aids to facilitate instrument approaches to airports,

and to provide flight advisory services. These are discussed separately as follows:

Enroute Aids - In assessing the requirement for enroute NAVAIDS, the frequency of flights and type of aircraft being operated are most important factors. The class of operation (i.e. scheduled, non-scheduled, or executive/private) is also considered. In addition, proposed facilities are rated as to their capacity to serve one or more airways, to provide holding or a fix for ATC purposes and to provide as a secondary function, a let-down capability. Capital, maintenance and flight checking cost factors must also be weighed. Where traffic is light a Non-Directional Beacon (NDB) usually precedes the installation of a more sophisticated facility (i.e. the VOR) which best serves high density areas.

Terminal Aids - The prevalence of adverse weather creates the requirement for terminal aids to permit instrument approaches, and the extent to which poor weather prevails is a major factor in determining the requirement and priority for an approach or landing aid. Another major consideration, particularly for ILS installations, is the type of operation and category of aircraft (i.e. scheduled, non-scheduled, executive/private class of operation using jet or propellor aircraft). Other considerations are the population served, the potential usefulness of the facility in any secondary role, the proximity of other bases with similar facilities and cost factors.

Aeradio Stations - These stations provide air/ground/air communications for flight advisory service, landing and take-off advisory service and meteorological observing service in some cases. They are located along airways or

air routes usually close to an airport. The factors which affect the decision to establish an aeradio station may be listed as:

- Service and communication channels required.
- Area over which required.
- Compatibility with existing facilities.
- Volume of IFR traffic (to a mandatory level).
- Volume of VFR traffic (a weighting factor only).
- Evidence that the traffic level will be maintained.
- Capital, maintenance and operating costs.

It should be noted that these criteria were developed some years ago and are in the process of being updated. They are, however, being used at present in assessing the requirements for new facilities.

VISUAL AIDS

By far the most important aid to visual navigation is the aeronautical chart. Fortunately, this is an area where much progress has been made in recent years as will be seen by the chart samples on display at the conference. The new shaded relief charts should be of particular interest to northern pilots who regularly fly visually. These charts will also be useful for IFR flights by crews on aircraft equipment with ground definition radar.

Other visual aids such as rotating beacons, visual approach slope indicators, runway identification lights, high visibility paint on buildings etc. are and will continue to be used at northern sites.

COMMUNICATIONS

In a land mass of a million and a half square miles with a population of only 50,000, many of which are nomadic, communications will always be a problem Substantial progress has been made during recent years as a result of technological developments such as new microwave transmission networks, modern teletype systems, etc. but there is still room for improvement.

Fast and efficient communications are essential to the aviation industry for flight planning, air traffic control, weather information, and notices to airmen(NOTAMS); also for search and rescue or other emergencies. Because of the vast distances and sparse population in the Arctic, communication costs are high and facilities are limited. However, telephone communications for Air Traffic Control purposes in the north are generally well established on three main routes out of Edmonton. The first route covers the Athabaska River, Great Slave Lake area and Northward to Hay River and Yellowknife. The second is the route through Peace River Fort Vermillion, Fort Simpson and down the Mackenzie River to Norman Wells and Inuvik. The third follows the commonly known "Staging Route" through Grande Prairie, Fort St. John, Beatton River, Fort Nelson, Smith River, Watson Lake, Whitehorse, Aishihik, Snag and Northway. Also a direct circuit connects Edmonton and Cambridge Bay where an interconnection provides vital telephone communications with Anchorage, Alaska and Sondrestrome, Greenland.

As commercial facilities are expanded and improved to the areas immediately west of Hudson's Bay and north to the Arctic Islands, Air Traffic Control circuits will probably be extended accordingly as traffic warrants.

The Ministry also operates a vast network of "Air to Ground" radio communication stations throughout the north. These facilities perform a valuable service not only to the air traffic operations but to the isolated communities as well where commercial facilities are limited. The "umbrella" of air-ground communications is tied together by a network of teletype and radio-teletype circuits in addition to the ATC circuits previously mentioned. This teletype network has recently been upgraded to a fully automatic system as far north as Inuvik, Cambridge, Churchill, Frobisher and Goose Bay where reliable landline facilities are available. At more northerly or isolated points, the network is extended by means of radioteletype and radiotelephone circuits.

III POSSIBILITIES FOR THE FUTURE

TECHNOLOGICAL DEVELOPMENTS

AIRCRAFT - AIRBORNE NAVIGATION EQUIPMENT

a) Doppler and inertial navigation equipment will come into more common useage in the larger aircraft.

b) Airborne receivers for OMEGA and DECCA weighing less than 25 pounds and priced in the $1-2,000 range will be available to light aircraft operators in the North.

c) Reliable crash position indicators at reasonable cost will be available to the light aircraft operator.

NAVIGATIONAL AIDS

There are many significant developments in this area applicable to northern navigation. Some examples are:

a) New solid state low power NDBs, which are very compact, can be battery operated and are relatively inexpensive.

b) Thermo-electric generators which burn propane fuel can be used to power equipment at remote locations. Such generators are limited at this time to 200 watts output and are extremely reliable. A 40 watt generator has been on test in Ottawa for nearly five years, operating at a full cost of 47.9 cents per day.

c) The OMEGA navigation system described previously has tremendous possibilities and could be the means of solving northern navigation problems at modest cost.

d) Improved aeronautical charts will assist pilots who are required to navigate visually.

e) Solid state equipment is becoming available that will be less expensive to purchase and maintain.

f) An ICAO study, AN 6/19-70/111 dated 23 June 1970 has highlighted certain areas or aspects of the approach-to-land procedures which appear to warrant further study. In this report, for the period 1961-69, the landing phase accidents resulting in fatalities, were only 13.4% of the total number of accidents, yet accounted for 41% of all passengers and crews killed in all the known accidents in scheduled and unscheduled commercial operations. Landing phase accidents are defined as undershoot/ terrain collision accidents and overshoot accidents.

Because of these statistics and the developments in CTOL, STOL and VTOL aircraft, the RTCA established SC-117, with the objective of developing a new microwave Landing Guidance System to meet future operational requirements. The Signal Format proposed for the new system will drastically reduce susceptability to siting problems and will permit the development of several configurations to meet the requirements of many types of airports and services. The aircraft operator would be able to install only the equipment necessary for the service desired.

g) Satellite navigation equipments will be available in the future. A communication satellite could be used for an aircraft tracking system in Northern Canada, as was demonstrated by the OPLE feasibility tests.

COMMUNICATIONS

a) The communications satellite could be the answer to many existing problems.

b) Successful application of a "joint-use" program could make better use of existing facilities. In this connection, "joint use" of existing facilities could be greatly aided by HF oblique incidence ionospheric sounder radiations from one of the major centres such as Resolute so that all aircraft would know the optimum traffic frequencies. Such a system, via reciprocity, could also insure more reliable flow of facsimile weather charts from Edmonton to Resolute.

IV CONCLUSION

The existing Arctic NAVAID system has evolved over the last thirty years to meet a variety of requirements - military, research development and community needs, some of which may no longer be valid. It is clear that our current requirements must now be reviewed to assess whether this system is still adequate. Also, a master plan for future development is needed before decisions can be made on adoption of new navigation systems or further takeover of military facilities.

It has not been possible in the time or space allotted to cover this subject in the detail it deserves. However, if this paper serves to generate discussion culminating in identification of our mutual problems and possible solutions, it will have served its purpose.

APPENDIX "A"

INVENTORY OF
ARCTIC NAVIGATION AIDS (AIR)

6 LOW/MEDIUM FREQUENCY RANGES

Burwash, Y.T.
Frobisher, N.W.T.
Yellowknife, N.W.T.
Watson Lake, Y.T.
Whitehorse, Y.T.
Teslin, Y.T.

4 TACANS (Military)

Alert, N.W.T.
Cape Dyer, N.W.T.
Resolute, N.W.T
Whitehorse, Y.T.

ADJACENT (Non-Cdn. Connecting TACANS)

Thule, Gr.
Eilson, Alaska
Elmendorf, Alaska
Sondrestrom, Gr.

LORAN

There are no LORAN chains in the Arctic. There is limited coverage of LORAN "A" using the USN transmitter at Cape Christian on the east coast of Baffin Island.

72 NON-DIRECTIONAL BEACONS

Civil Air (MOT)	33	(Including 7 Air/Marine)
Marine	1	
Military	21	
DIAND (Dept. of Indian Affairs & Northern Development) Now maintained by Gov't of NWT but not operated continuously.	17	
	72	NDBs

FOR LISTING SEE PAGE 20.

* There are also a number of special private company NDBs which are not published.

4 INSTRUMENT LANDING SYSTEMS

Frobisher, N.W.T
Inuvik, N.W.T.
Whitehorse, Y.T.
Yellowknife, N.W.T.

NON-DIRECTIONAL-BEACONS

(LISTED BY IDENTIFIERS)

* DND

\+ ALSO LISTED AS MARINE

Station	IDENT.
Komakuk, Y.T.	AJ
Fort Chimo, P.Q.	AX
Baker Lake, N.W.T.	BK
*Brevoort, N.W.T.	BZ
Cambridge Bay, N.W.T.	CB
Coppermine, N.W.T.	CO
Chesterfield Inlet, N.W.T.	CS
Munn Bay, N.W.T. (Coral Hbr)	CZ
[Coral Harbour (Marine)]	ZS
Dawson, Y.T.	DA
+Eskimo Point, N.W.T.	EK
Eureka, N.W.T.	EU
Inuvik, N.W.T.	EV
Fort Resolution, N.W.T.	FR
Fort Simpson, N.W.T.	FS
Frobisher, N.W.T.	FY
Fort Good Hope, N.W.T.	GH
+Cape Hopes Advance, P.Q.	HA
Hay River, N.W.T.	HY
Isachsen, N.W.T.	IC
Laberge	JB
Alert, N.W.T.	LT
Mayo, Y.T.	MA
Mould Bay, N.W.T.	MD
West Arm, N.W.T.	MG
Dolomite, N.W.T.	NF
Robinson, Y.T.	PJ
Resolute, N.W.T.	RB
*Resolution Isl., N.W.T.	RE
Rankin Inlet, N.W.T.	RT
Cape Martyr, N.W.T.	RU
Fort Smith, N.W.T.	SM
*Shingle Point, Y.T.	UA
*Tuktoyaktuk, N.W.T.	UB
*Nicholson, N.W.T.	UC
*Cape Parry, N.W.T.	UE
*Pelly Bay, N.W.T.	UF
*Rowley, N.W.T.	UG
*Clinton Point, N.W.T.	UH
*Cape Young, N.W.T.	UI
*Lady Franklin, N.W.T.	UJ
*Byron Bay, N.W.T.	UK
*Jenny Lind, N.W.T.	UQ
*Gladman Point, N.W.T.	UR
*Shepherd Bay, N.W.T.	US
*Mackar Inlet, N.W.T.	UU
*Longstaff Bluff, N.W.T.	UV
*Dewar Lake, N.W.T.	UW
*Hall Beach, N.W.T.	UX
*Cape Hooper, N.W.T.	UZ
*Broughton, N.W.T.	VM
*Cape Dyer, N.W.T.	VN
Norman Wells, N.W.T.	VQ
Takhini, Y.T.	WX
Wrigley, N.W.T.	WY
Lakeshore, Y.T.	XG
Yellowknife, N.W.T.	ZF
Coral Harbour, N.W.T.	ZS

CIVIL (AIR)	33
MARINE	1
MILITARY	21
TOTAL	55 STATIONS

PROPOSED NAVIGATIONAL AIDS

NDB's

Fort Reliance	1970-71
Fort Smith	1970-71
Port Radium	1973-74
Teslin	1971-72
Watson Lake	1973-74

ILS's

Hay River	1971-72
Watson Lake	1974-75
Fort Chimo	1972-73
Fort Smith	1973-74

VOR's

Watson Lake	1972-73
Whitehorse	1971-72
Yellowknife	1973-74
Frobisher	1970-71
Fort Chimo	1971-72

DME's

Watson Lake	1972-73
Whitehorse	1971-72
Yellowknife	1973-74
Frobisher	1971-72

ARCTIC AIRPORTS

BY: M. BARIBEAU, REGIONAL DIRECTOR
AIR SERVICES, MONTREAL
& R. S. NOWLAN M.O.T. OTTAWA

INTRODUCTION

AVIATION has long been recognized as the key to open the North. Some of the milestones since the first World War include exploration flights and air surveys starting as far back as 1919, with regular mail, freight and passenger services commencing in the mid-twenties and continuing through the thirties. Oddly enough, some of the earliest exploration flights were initiated to search for a "Northwest Passage By Air" and this has only recently become a reality with several international air carriers now flying trans-polar routes.

Reliability of service had increased sufficiently by 1938, that Civil Aviation authorities in Ottawa decided to extend air mail service to the Yukon and down the Mackenzie River to the Arctic coast. This required development of what ultimately became the Mackenzie and Northwest Staging Routes. Work was underway in 1939 when Canada entered the war and it was decided at that time to expedite construction as the strategic importance of these inland routes to the north was recognized. As a result, Canada was able to offer free use of a safe inland airway, equipped with modern aids to navigation, to the United States when they entered the war in 1941.

During the course of the war, other major airports such as Churchill and Frobisher were built and these have subsequently been taken over for civil use.

In the 1950's came the DEW line and its associated chain of airfields along the Arctic coast. Since the war, a number of airfields have been built in the Arctic to support mining or oil exploration projects but only a few, such as Inuvik, have been developed specifically to meet civil requirements or community needs.

The Ministry of Transport now has an investment of 76 million in Arctic airports and annual direct operating costs amount to 4.5 million excluding the Joint Arctic Weather Stations. With the recent increased emphasis on sovereignty and resource development in the Arctic, it is likely that this investment will continue to grow. To get full advantage from future expenditures, a carefully thought out overall development plan will be essential. Before such a plan can be developed, it will be necessary to determine:

A) Potential demand for air transportation in the Arctic;

B) Adequacy of the existing airport system to meet this demand;

C) Phased development necessary to meet future requirements.

It is proposed to present our views on each of these broad areas in this paper as a starting point for discussion at the Arctic Transportation Conference.

THE EXISTING AIRPORT SYSTEM

There are on record some 88 land airfields and 62 seaplane bases located in the Arctic. In addition, abandoned airfields developed by resource exploration companies are still used on occasion by local pilots familiar with their condition. Also, unprepared seaplane or ski areas are regularly used to serve remote communities or field parties except during breakup and freezeup periods. These facilities serve a one and a half million square mile land mass with a population of approximately 50,000. There are some 250 established settlements but more than half of the total population is nomadic.

The primary role or purpose served by individual aerodromes in the existing system has in most instances changed several times over the years. Typically, they started as small community airfields, were developed extensively to meet a military requirement, and have since reverted back to civil authorities. Others were originally built for resource development purposes and now serve the communities that have since been established. Approximately one third are still operated primarily for military or scientific purposes.

Essentially the Ministry of Transport assumes full responsibility for construction and maintenance of airports required in support of regular commercial air services operating with a frequency of at least 50 scheduled arrivals and departures per annum.

Additionally, the MOT has a policy which provides for a cost sharing, financial assistance approach

up to a maximum of $100,000 for the construction of airports required to relieve isolation in communities or settlements not served by reliable methods of surface transportation on a year-round basis. The determination of need and the extent of Ministry participation up to the $100,000 maximum is established on the basis of consultation with DIAND and other government departments and agencies. These policies are now under review and may be changed with effect on 1971-72 and future programmes. With regard to private airport development, the Ministry provides technical advice on request and ensures that adequate safety standards are maintained.

In assessing adequacy of the existing airport system, certain problem areas are apparent as follows:

a) Many of the former military airfields that have been phased out and taken over for civil use as local community airports are overdeveloped for their present role. Consequently, they are complicated and costly to maintain.

b) Special purpose airports such as those developed for research or military purposes are usually equipped only for this primary activity and their use for other purposes is discouraged.

c) Existing airports were, in many instances, sited to meet requirements other than for which they are now being used. Before major capital expenditures are made at such locations, site suitability studies should be undertaken to ensure that they are suitably located to meet present and anticipated future requirements.

d) Pollution, while not a major problem at this time, is already apparent at many northern sites in the form of oil drums from abandoned fuel caches.

e) Costs are prohibitive for new "local" airports if these are built to specifications now established for airports in the more developed areas of the country.

f) Operating costs for Arctic airports are high and personnel are not easily recruited for the more remote sites. Salaries and accommodation can amount to $18,000 annually per man at such locations.

g) Because of the extended periods of darkness which exist for a large portion of the year in the Arctic region, airport lighting which meets the Ministry Standards will be required if the maximum utilization is to be achieved.

FUTURE AIRPORT DEVELOPMENT

Forecasting future airport requirements in the Arctic calls for a somewhat different approach than that taken for the more developed areas in Canada. This is primarily because the requirements for airports differ in the North. For example, the primary role of airports in the existing system can be divided in the following general categories:

Transportation Transhipment Hubs
Resource Development
Research
Military
Local Community
Technical Support

In our view, potential development in each of these categories will have to be forecast separately, then melded into an overall forecast for the Arctic. This will be a formidable undertaking far beyond the scope of this paper. However, certain general trends are apparent and these will be set forth as a basis for discussion at the meeting along with our observations as to the feasibility of forecasting development in the various categories.

TRANSHIPMENT HUB AIRPORTS

As indicated on the chart (Appendix A) six major airports fall into this category - Whitehorse, Inuvik, Yellowknife, Churchill, Frobisher and Resolute. Each of these is located at a terminating point for surface transportation. It can be expected that development of these

airports to meet operational requirements will continue subject to availability of funds. Whether additional "hub" airports will be developed is more difficult to predict. This would most likely occur as a result of a new harbour or other surface transportation terminal being established. For example, operations out of Hay River are increasing as a result of the railroad and this airport may develop into a major transhipment centre over the next few years.

RESOURCE DEVELOPMENT AIRPORTS

There is little doubt that new airports will be required in the Arctic to facilitate resource development. However, the location and sizing of such facilities is not predictable in advance.

In the past, major mineral finds have generated heavy air traffic at airports ill equipped to handle such activity. To avoid potentially hazardous conditions developing in future situations of this type, it may be worthwhile considering the establishment of a mobile task force equipped to beef up existing facilities and services. (The Canadian Forces already have this capability and the feasibility of their resources being utilized for this purpose could be explored in any subsequent "joint-use" study.)

RESEARCH AIRPORTS

Existing airports in this category include the Joint Arctic Weather Stations. While it is expected that there will be a continuing requirement for these sites, technological advances could alter the picture.

The possible requirement for new scientific bases is not predictable with any degree of accuracy.

MILITARY AIRPORTS

As in the previous category, the possible future requirement for new military aerodromes is not predictable. However, plans for taking over existing aerodromes when they are no longer required for military purposes can and should be formulated in advance. Often, such takeovers come up on short notice as a result of a policy decision and there is little time to assess whether or not a valid civil requirement for the facility exists. Advance planning would reduce the possibility of mistakes being made in such instances.

LOCAL COMMUNITY AIRPORTS

There are some 250 communities in the Arctic and all are to some extent dependent on air transportation. However, only a few have an airport. The others can usually be served by seaplanes in summer or with ski equipped aircraft in winter but during spring and fall breakup, they are completely isolated.

In most instances, an airport is a vital necessity to northern communities as it is often the only link with the outside world during spring and fall breakup to say nothing of providing a year-around means of transport for mail, passengers and perishables. However, a single gravel strip 3,000 feet long can cost a quarter of a million dollars. Also, operating costs are high and revenues are usually minimal due to low traffic density. Therefore, northern airports are not an attractive investment for either government or private enterprise.

As a result, it is likely that new airport development will be limited to the larger communities for economic reasons and the others will have to continue making do with ski and float plane service.

TECHNICAL SUPPORT AIRPORTS

It has been necessary in some instances to build airfields at remote locations where navigational aids are located to provide access for servicing, operating personnel, fuel, etc. With long range navigation facilities such as OMEGA becoming available and with the introduction of solid state, battery or thermal generator operated NDB's, this practice will likely diminish.

The existing Arctic airport system has evolved over several decades and two wars - one hot and one cold. Facilities have been developed to meet a wide variety of both military and civil requirements, many of which may no longer be valid. Before further major expenditures are made to enlarge existing facilities or develop new ones, the present system will be critically examined to see if it adequately meets our current requirements. Then a master development plan based on the best available forecast of future operational requirements will be prepared.

Such a plan is far beyond the scope of this paper but in our view development of northern airports during the foreseeable future will be along the following general lines:

a) The major transhipment hub airports will be further developed to meet operational requirements of the

larger aircraft now coming into service.

b) We can expect that there will be requirements for new "Resource" airports periodically.

c) Limited further development of existing "Research" airports can be expected.

d) Some existing "Military" airfields may become surplus to military requirements and available for civil use.

e) Development of "Local" airports to serve the larger communities will continue subject to availability of funds.

f) It will not likely be necessary to develop more "Support" airports at remote NAVAID sites and possibly some that are now in operation can be phased out.

g) Technological changes may modify our remote airport requirements (See Discussion Item, Appendix 'B').

PROBLEM AREAS

In preparing for the future, it is usually sound practice to identify present and past problem areas. Some of these are listed below together with our views as to possible solutions.

PROBLEM

Overloading of existing airport facilities as a result of mineral strikes or searches for lost aircraft.

POSSIBLE SOLUTION

Develop task force(s) equipped with mobile control tower, field lighting and maintenance equipment, electronic landing aids, etc. Such units could maintain proficiency if deployed to existing sites during seasonal peak traffic periods.
i.e. Tuktoyaktuk or Resolute during summer months.

PROBLEM

Special purpose airports such as those developed for research or military purposes are not equipped to handle other traffic and discourage potential users.

POSSIBLE SOLUTION

Where practicable, equip such airports to accommodate other traffic. While this may not be a paying proposition, it would be much cheaper than developing separate facilities.

PROBLEM

Development costs for new local airports prohibitively high.

POSSIBLE SOLUTION

a) Investigate feasibility of STOL/VTOL operations from nearest hub airport during spring breakup and fall freeze-up periods. (See Appendix 'B' also).

b) Explore ways to develop airfields at less cost without compromising safety.

c) Broaden approach to financing by enlisting aid of other government agencies who benefit from facility.

d) Review existing design specifications to ensure that they are applicable to Arctic conditions.

PROBLEM

High operating costs for local or community airports.

POSSIBLE SOLUTION

a) Keep such developments as uncomplicated as possible to avoid need for skilled personnel.

b) Investigate the feasibility of a training program for local labour to avoid need of importing staff.

CONCLUSION

As previously indicated, the purpose of this paper is to generate discussion at the forthcoming Arctic Transportation Conference. It is hoped that this discussion will help identify both problems and possible solutions in order that these may be considered when future development plans are being formulated.

ARCTIC TRANSHIPMENT HUB AIRPORTS

APPENDIX "B"

DISCUSSION ITEM

Extract from "THE SOVIET PRESS ON THE SOVIET NORTH"
August 1970

"The airship represents the sole means of fully solving the problem of transportation in the outlying districts of Siberia, in the Far North and in the Far East. Most dependable of all flying devices, airships might carry cargo of practically any size, weighing hundreds of tons, over distances of thousands of kilometres, in order to supply the underdeveloped regions of the Soviet Union.

An airship represents the cheapest means of air transport. It needs 5 to 15 times less power than an airplane or a helicopter, respectively. As of now, it is already possible to increase its speed up to 200-250 kilometres per hour.

A design for the first all-metal airship already exists. Known as "TsM-100" the project airship, with a commercial cargo capacity of 100 tons, would run without any ballast. It does not discharge gas upon landing and can be berthed anywhere on the ground. Reaching speeds of up to 210 kilometres per hour and capable of uninterrupted travel over distances of up to 23,000 kilometres, this new type of airship does not require mooring facilities for parking and it is no longer threatened by the fire hazard. In addition to transporting passengers, it might be utilized as a crane for lifting freight. *(or a mobile hospital and dental clinic.)*

Airships might well become indispensable as carriers of heavy construction parts, due to the possibility of suspending loads therefrom and their large cargo compartments.

In the U.S.A., where hard top roads are far more plentiful than in the Soviet Union, airship fleets do exist. From 1951, several new types of airships have been used there, including those with the capacity of transporting up to 1,000 tons of cargo."

APPENDIX "C"

PROPOSED LAND AIRFIELDS

MOT

BEAVER CREEK Y.T.	69-70
COPPERMINE N.W.T.	69-70
CAPE HOPES ADVANCE (KOARTAK)	72-73

DIAND

PANGNIRTUNG	71-72
ESKIMO POINT	71-72
FORT MCPHERSON	72-73
AKLAVIK	72-73
CHESTERFIELD INLET	72-73
POND INLET	73-74
WHALE COVE	73-74
IGLOOLIK	75-76

METEOROLOGICAL SERVICES IN THE ARCTIC

BY: F.W. BENUM
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1. INTRODUCTION

Weather has been one of the major factors hindering Arctic development in the past and any plans for future development will require a detailed knowledge of its occurrence and its effect on man and his activities. This is especially true in the field of transportation. The safety, efficiency and cost of aviation operations, one of the principal means of transport, are all dependent on weather, while marine transport, traditionally subject to the weather, may be even further affected by Arctic gales and low temperatures or visibilities.

In the past, transport within the Arctic has often been forced to operate with inadequate weather information but the present rapidly increasing level of activity in both the public and private sectors, together with the extension of such activity into new and undeveloped areas, has created demands for expanded meteorological services which require an increase in the supporting resources and facilities. In particular, the major expansion in air and water routes and the building of new airports, requires a major increase in the weather observing network and in the frequency of observations, more frequent and accurate weather forecasts covering larger areas, coupled with new or improved means of communicating or presenting this information to the user.

2. OBJECTIVE

The Canadian Meteorological Service (CMS) of the Ministry of Transport (MOT) is the federal agency responsible for:

(1) The provision of meteorological and ice information services in response to the needs of a broad spectrum of segments of the national economy, and,

(2) For promoting the application and development of meteorological and ice services in Canada.

This objective applies to Canada as a whole, including the Arctic, but because of the severity of the climate it may assume even greater importance there. This paper is a review of the meteorological services in the Arctic in the light of this objective.

3. THE APPROACH

Meteorological services are determined by the requirements of the general public together with the special requirements of the most important economic activities and their supporting services in an area. The meteorological services required will, in turn, determine the necessary supporting resources and facilities. An attempt is made, therefore, to assess:

(1) The present and future development of the Arctic economy.

(2) The requirement of these activities for meteorological services.

(3) The adequacy of present services.

(4) The additional resources and facilities necessary to provide the full services.

4. ARCTIC ECONOMIC DEVELOPMENT

The most important primary and supporting activities in the Arctic may be summarized as follows:

(1) Oil and Gas Exploration and Development. This is the most important economic activity at the present time and promises to increase in the future.

(2) Oil and Gas Transportation. The transportation of oil from the Arctic, either by tanker or by pipeline, promises to be a major activity in the future. Very large expenditures on pipeline construction seem possible.

(3) Mineral Exploration and Development. Mineral production is increasing at a rapid rate and minerals presently constitute the principal economic product of the area. Other major mineral deposits await development of transportation.

(4) Air Transportation. Much of the activity in the Arctic depends on air transportation and this has been expanding at a very rapid rate, particularly along the Mackenzie Valley. Ten new development airports are planned over the next ten years. Traffic at certain Arctic airports such as Yellowknife, Inuvik, Resolute and Frobisher has increased by 200-300% in the past five years and now exceeds that at many airports in Southern Canada.

(5) Water Transportation. The possibility of transporting oil by means of very large reinforced tankers is under active investigation. There is an increasing requirement for the transport of oil drilling equipment by water. Development of major mineral deposits in the Arctic will require water transport.

(6) Construction and Engineering. Construction and engineering activity is rapidly expanding in conjunction with oil and mineral development, and government development projects. Value of such projects has expanded 500% in the past 4 years.

(7) Scientific Studies and Exploration. Such studies form a significant part of the Arctic economy and have special requirements for meteorological services.

These are reviewed in greater detail as follows:

4.1. Oil Exploration and Development

Most recent figures indicate that a total of $70 million was spent on oil and gas exploration in the Arctic in 1969. Forecasts prepared by the Northern Economic Development Branch of DIAND indicate that this will increase to an annual rate of $130.6 million in 1974, with total expenditures in the period 1970-74 amounting to $518 million if all commitments under Canadian Oil and Gas Land Regulations are met. Present activity and planning indicates exploration will be centred in three general areas - (i) The Mackenzie Delta and the Arctic Coastal Plain from Alaska east to Cape Parry, including offshore areas; (ii) the Arctic Islands with primary activity centred around Melville Island; (iii) the Hudson Bay. These areas are listed in order of importance.

Current planning calls for 15 wells to be drilled in the Arctic Islands by the spring of 1971. If there were a major oil discovery the rate of drilling would increase very greatly. An even larger number may be completed on the Arctic mainland in the same circumstances.

4.2. Oil Transportation

No firm decision has yet been reached on transportation of Alaskan oil or gas plus any oil or gas that may be discovered in the Canadian Arctic, but present planning is based on use of one or more of the following means:

(1) Oil pipeline - across Alaska and possibly down the Mackenzie Valley.

(2) Oil tankers of very large capacity operating through the Northwest Passage to Europe and the East coast of the U.S.A.

(3) Gas pipeline down the Mackenzie Valley.

A trial run of a large specially reinforced tanker from the East Coast to Alaska was made in the summer of 1969, while several companies have announced plans for pipeline construction. A decision on the above alternatives is expected in 1970 or 1971. Estimates on the cost of a gas pipeline alone down the Mackenzie Valley range from $2 to $4 billion.

4.3. Mineral Exploration and Development

Mineral production has increased from $32.8 million in 1964 to $153

in 1969. In addition new mineral deposits of considerable size have already been located in several areas in the Arctic including large iron ore deposits in northern Baffin Island and the Central Yukon areas, lead-zinc deposits in Baffin Island, etc. Prospecting and drilling is also being carried out at a number of other sites in the Central Northwest Territories including Bathurst Inlet, Pelly Lake, Artillery Lakes, Lac la Morte. In some cases development of operating mines only awaits solution of the transportation problem.

4.4. Air Transportation

The lack of road or rail transport throughout the major part of the Arctic means that air transportation is of high importance as the primary means of transport over large areas. Nearly all current economic development depends on support by aircraft. Air transport is highly sensitive to weather and requires a sophisticated system of weather services.

4.4.1. Air Routes

There are four major access routes for scheduled commercial traffic from Southern Canada to the Arctic - i.e. Vancouver-Whitehorse, Edmonton-Yellowknife-Inuvik, Winnipeg-Churchill and Montreal-Frobisher with extensions of these services at reduced frequency to Baker Lake, Resolute Bay, Cape Dyer and Cambridge Bay. Scheduled feeder routes extend from the principal Arctic terminals of Whitehorse, Yellowknife, Inuvik, Resolute, Churchill and Frobisher to other Arctic airports. In addition a requirement has been stated for an East-West route across the Arctic connecting Frobisher Bay and Yellowknife through Rankin Inlet or Churchill.

4.4.2. Airports

The more recently available statistics indicate that on the basis of aircraft movements the eleven principal Arctic airports can be ranked as follows:

	Total Itinerant Aircraft Movements January-June 1970
Whitehorse	11068
Inuvik	8340
Yellowknife	6508
Normal Wells	5428
Resolute Bay	3385
Frobisher Bay	2741
Fort Smith	2725
Hay River	2559
Churchill	2294
Fort Simpson	1369
Cambridge Bay	983

Traffic has shown the maximum increase at Inuvik and other airports along the Mackenzie Valley such as Normal Wells and Fort Simpson, as

well as at Resolute. Temporary bases are being established by the various oil companies for the movement of supplies, equipment and personnel including a major strip at Rea Point on Melville Island under Panarctic Oil. Operation and services at such strips are normally the responsibility of the company. Under an agreement authorized in 1969 the Ministry of Transport has undertaken to supervise construction of eleven development airports in the Arctic for DIAND. These airports are to be constructed over the ten-year period 1970-80 and consists of:

Name	Construction to Start
Coppermine	(presently near completion)
Pangnirtung	1971 - 72
Old Crow	(under construction 1970)
Eskimo Point	1971 - 72
Fort Macpherson	1972 - 73
Aklavik	1972 - 73
Chesterfield Inlet	1972 - 73
Pond Inlet	1973 - 74
Whale Cove	1973 - 74
Igloolik	1974 - 75
Cape Dorset	1975 - 76

As a result of increasing civil traffic a proposal has also been made that the Canadian government take over operation of certain DEW Line airports. Those presently under consideration are: Cape Dyer; Hall Beach; Cape Parry; Tuktoyatuk.

4.5. Water Transportation

An attempt was made in 1969 and the spring of 1970, to determine the feasibility of moving oil by large reinforced tanker through Arctic ice. If the assessment of this project is satisfactory, it will be developed into an operation continuing through the greater part of the year and operating through the Northwest Passage to Europe. Water transport would also be required for development of lead/zinc mining in Strathcona Sound and large iron ore deposits at Mary River in Northern Baffin Island. None of these projects has yet been decided. Water transport down the Mackenzie River is expanding at a very rapid rate with a corresponding expansion east and west from the Mackenzie Delta along the Arctic Coast.

4.6. Construction and Engineering

While complete figures on the value of construction and engineering projects in the Yukon and Northwest Territories are not readily available, development in this industry must parallel that in the basic industries noted above. Construction of pipelines along the Mackenzie, extensive mining installations in Northern Baffin Island, additional airports or a new harbour along the Arctic coast are all possible within the next three years, but none are yet confirmed.

4.7. Scientific Studies and Exploration

Significant additions and expansion are expected to the programs in existence in previous years. One change has been the shift of the main operating base for the Polar Continental Shelf Project from Mould Bay to Tuktoyaktuk in 1969. This has resulted in an important increase in air traffic at Tuktoyaktuk, an airport already expecting heavy traffic from oil exploration and drilling.

5. REQUIREMENTS FOR WEATHER SERVICES

Because of the severity of the Arctic climate, activities are conducted, wherever possible, in a sheltered environment. In those cases where this is not possible, weather information assumes a high degree of importance.

There is considerable variation in the need for weather services of each of the economic activities listed above. Some, such as underground mining, may be conducted regardless of current weather, while others, such as air transportation, are highly sensitive. Previous studies and experiences have established certain basic requirements for weather information and service of those activities of importance to the Arctic as follows:

5.1. General Requirements

For basic living and operating in a severe Arctic climate accurate general forecasts as given in the present Public Forecast Program should be available for major population centres and for areas with significant economic activity.

5.2. Air Transportation

(1) Hourly reports and specials from airports within two hours flying time;

(2) Reports from intermediate stations sufficient to depict en-route weather for VFR flights;

(3) Aerodrome forecasts for the first destination and alternates where forecasts for the remainder of the route will be available;

(4) Area forecasts including upper winds as required for preflight briefing or supply to aircraft in flight.

(5) Presentation service as required.

As an interim statement of policy on (5) it is proposed that a requirement for presentation service exists at those airports identified as:

(1) Flight planning points for longer range scheduled services;

(ii) Major traffic centres (over 2,000 flights per year);

(iii) Operating base for several feeder airlines or charter services.

5.3. Water Transportation

(1) Marine weather forecasts covering the planned route for periods up to 48 hours in advance.

(2) Wave forecasts for area of operation for periods as far in advance as science permits.

(3) Harbour forecasts for departure and arrival points covering periods of loading and unloading.

(4) Current weather observations from ships and coastal stations covering the immediate area of operation.

(5) Short range warnings of conditions hazardous to shipping including wind, waves, fog and freezing spray.

5.4. Oil and Mineral Exploration and Development (excluding associated transportation)

For short range planning for operations on land the information required is the same as that contained in the Public Forecast. For long range planning of operations such as the movement of heavy equipment and for designing adequate shelter and suitable machinery, accurage and complete climatological information is required. When conducted offshore, oil drilling and exploration will also require predicted and historic wave data for those areas in the immediate vicinity of their operations.

5.5. Oil Transportation

Due to problems with oil viscosity, oil pipelines might be expected to require accurate data (climatological and predicted) on temperature. Oil tankers would require Marine Forecasts for their operating route as indicated under "Water Transportation".

5.6. Government Development Projects and Construction

In the planning stage the principal requirement is for accurate climatological data and consultative service. In the construction phase accurate short range (12-24 hours) forecasts are required of elements such as temperature, wind and precipitation.

6. REQUIREMENTS FOR IMPROVED OR ADDITIONAL SERVICES

From the review of the most important activities in the Arctic and from the general statement of their requirements for weather service given

above, it is possible to assess current programs to determine present deficiencies as well as the additional services required. In assessing such programs due account must be taken of the specific locations or areas for which information is required and the locations where the information should be available, the periods of time it should cover and the times it should be available.

Programs fall in three general fields of service:

(i) Historic Data (climatology)

(ii) Current or basic data (observations)

(iii) Predicted data (forecasts)

6.1. Climatological Data

Requirement

(1) Preparation and publication of regional studies of pertinent climatic factors for the entire arctic to allow the preparation of representative design values to be used in the planning and design of townsites, airports, buildings, equipment, together with related communication, transportation and service facilities.

(2) Consultation and applied climatological studies involving analysis and research on the occurrence of specific weather phenomena in various Arctic regions.

Deficiencies in Current Service

Not enough climatic data are available from Canadian Arctic regions to allow the preparation and publication of design values and for the provision of other meaningful advice, information and data. The sparse settlement within the Arctic does not permit a large expansion in the network of manned weather stations.

Additional Services Required

(1) Preparation and publication of regional studies of pertinent climatic factors.

(2) Preparation of studies in depth for specific locations and activities.

(3) Additional analysis and research on Arctic Climatology.

Additional Resources or Supporting Services

The development of additional sources for climatic data will require action as follows:

(1) Accelerated development of instrumentation for automatic weather stations (target date 1972).

(2) Early installation and operation of such stations at a number of Arctic sites (1972-75).

(3) The development of new manned sites.

The provision of additional services in Arctic Climatology will require an expansion in the present professional and technical staff, together with an increase in costs for automatic data processing.

6.2. Predicted Data (forecasts)

Requirement

(1) Public Forecasts covering the areas and periods with significant economic activity together with routine local forecasts for the more important population centres.

(2) Special forecasts as required for construction, development and surface and transport, etc.

(3) Aviation Terminal Forecasts - on a routine basis for airports with scheduled service or with a significant number of unscheduled flights each day and for other airports on request.

(4) Aviation Area Forecasts and Upper Wind Forecasts - to cover all present Aviation Forecast Regions with significant aviation activity.

(5) Marine Forecasts - to cover the principal shipping routes during the period of navigation.

Deficiencies in Current Services

Forecasts are being issued for all areas and periods that are required at present. The accuracy of the forecasts, however, is adversely affected by an inadequate basic network in the Arctic particularly in the area surrounding Viscount Melville Sound and in the central Northwest Territories between Fort Reliance and Baker Lake.

Additional Services Required by 1973

(1) More frequent Public Forecasts to cover additional areas in

the Arctic.

(2) Extension of the season for issuing Marine Forecasts.

(3) Special Forecasts to cover major construction and development projects.

(4) Additional Aviation Terminal Forecasts to cover extensions of scheduled services and new airports or for airports where present data are inadequate for routine forecasts.

Additional Resources Required

Studies at the offices responsible for preparation of basic forecasts for the Arctic have shown that present authorized forecast staff is adequate to meet current requirements. In addition, the offices responsible are capable of handling a limited expansion in output as described above. The principal requirement is therefore a more adequate basic network for forecasting purposes.

6.3. Presentation Services

Requirement

Presentation services are provided at major centres of air traffic, where flights are frequently planned or which constitute the operating bases for several feeder airlines or charter services, or at principal centres of development activity. The following locations in the Arctic meet these qualifications and should be staffed and equipped to provide such service:

(1) Whitehorse
(2) Yellowknife
(3) Inuvik
(4) Resolute Bay
(5) Churchill
(6) Frobisher

These offices would then form basic centres or hubs for the supply of meteorological information, consultation and advice to operations in their vicinity, using available means of communication.

Deficiencies in Current Services

Yellowknife - Present staff is unable to handle all observing and presentation duties. Additional staff is required.

Inuvik - The present staff and classification of this office (Weather Station) appears inadequate to the present type and amount of activity. Latest figures available for Inuvik Airport indicate nearly 2,000 itinerant aircraft

movements per month, an increase of 500% over the same month of 1967. As the principal airport serving the most actively developing area of the Delta and the Arctic, there would appear to be a requirement for this office to rise to the status of a Weather Office and be provided with staff sufficient to provide briefing services 24-hours per day together with dependable teletype and facsimile communications.

Resolute Bay - This is the principal airport and communications hub supporting activity in the Central and Western Arctic Islands where considerable development activity is indicated. Total air traffic is presently comparable to Frobisher Bay but is increasing rapidly. Present staff is not sufficient to cover requirements for presentation during periods of maximum activity (April September). Two additional Technicians are required in this period.

Whitehorse - Churchill - Frobisher - Staff and facilities appear adequate for current and foreseen service requirements at these locations.

Additional Services Required

With the exception of the reclassification of the Inuvik office, there has been no proposal for new Presentation Offices in the period under review. As noted above, aviation companies have not yet indicated any major transfer of operations from Yellowknife to Hay River. The additional services required would appear to consist of an increasing volume of work centred primarily at Yellowknife, Inuvik and Resolute Bay.

6.4. Current Data

Requirement

(1) Hourly Weather Reports from airports with scheduled services and from other airports and enroute stations as required by volume of traffic and as justified by available navigation aids, etc.

(2) Surface synoptic reports at 6-hour intervals sufficient to accurately delineate synoptic weather systems (normally 200 - 300 mile intervals).

(3) Upper Air (radiosonde) reports at 12-hour intervals sufficient to accurately delineate upper air temperature and flow patterns (normally 400 - 600 mile intervals).

(4) Additional observational data such as satellite readouts to supplement the sparse surface network.

Deficiencies in Current Services

Hourly Observations

1. Scheduled Air Services

A review of the services at airports in the Arctic indicates that hourly observations are being made available at all airports with scheduled service with two exceptions:

1.1. Tuktoyaktuk - This airport presently is one of the Dewline locations. 6-hourly observations are taken on a routine basis. A scheduled service Inuvik-Tuktoyaktuk-Sachs Harbour was initiated on a weekly basis in the fall of 1968 by Great Northern Airways. The airport lies in the centre of the Mackenzie Delta region where oil development is most active and has good potential for development of harbour facilities for large vessels. For the next two or three years it will also be the principal base of the Polar Continental Shelf Project formerly based at Mould Bay. Traffic figures are not available, but during early 1970, there were as many as 20 flights per day from Inuvik with probably larger numbers from other locations. Hourly aviation observations are presently being provided by the Polar Continental Shelf Project, as other duties permit. Present plans call for limited hourly observations on a contract basis in 1972-73. Teletype connection is also required to Inuvik.

1.2. Rankin Inlet - This airport, owned and operated by DIAND, is not presently equipped for weather observations - though there may be unofficial observations taken. It is served three times weekly by Transair on a scheduled service from Churchill to Baker Lake. Requests for weather observing facilities have been made by the Northwest Territories Council and by DIAND. This project is in the present 5-year Plan for 1971-72.

2. Unscheduled and Charter Services

While the network of hourly surface observations would appear reasonably adequate to meet the needs of scheduled commercial operations, the same situation does not apply to non-scheduled charter or private operators. For operations of this nature, which are not confined to established routes, weather observations are extremely sparse or completely missing over large areas. Although this has constituted one of the principal deficiencies in service to aviation in the Arctic, there have always been several obstacles to an easy solution:

(i) Weather observers. Many areas have no permanent residents, while in others residents lack necessary education or time to undertake regular observing duties.

(ii) High costs. The cost of establishing and maintaining an observing station in isolated Arctic locations amounts to several times the cost of a similar station in Southern Canada.

(iii) Varying requirements. There is a high degree of variation in the volume of unscheduled flights in various areas, both from season to season and from year to year. In these circumstances it is not economic to make the large capital expenditures necessary for a permanent observing station.

(iv) Communications. Current data is only of use to aviation if it can be distributed to the user with a minimum delay. In the Arctic this usually means suitable radio transmission facilities.

To present a more complete and detailed picture of general weather conditions over the Arctic and to avoid the problems outlined above, it is suggested that, as a first step, maximum use should be made of existing facilities, personnel and wherever possible, permanent local inhabitants. This could involve the following changes:

2.1. Joint Arctic Weather Stations (Isachsen, Eureka, Mould Bay Alert)

While the amount of air traffic landing or taking off from these stations does not appear to require hourly observations on a continuous year-round basis, they represent almost the only source of information on general flying conditions over large areas of the Arctic Islands. As such the present program of 3-hourly observations, with hourlies on request, does not appear to use their full potential. As the only manned and equipped observing locations the observing program at these stations should be increased to a full program of hourly observations during the period April to October, with hourlies to be supplied on request during remaining months.

2.2. Dew-Line Stations

Hourly observations are presently available from only 50% of these stations, the remainder reporting on a 3 or 6-hourly basis. Consideration should be given to increasing the frequency of observations to hourly in those areas and in the period of major activity - i.e. west of Cambridge Bay and in the period April-October.

2.3. Development Airports

To further increase the density of hourly observations, arrangements should be made at each of the DIAND-DOT Development Airports

listed above, as they are constructed, to provide meteorological instruments, observer training and suitable communications to enable them to provide hourly observations during the months April-October.

2.4. Special Airstrips and Operating Bases

Companies developing special airstrips and operating bases should be encouraged to take and transmit observations on a regular basis by providing them with meteorological instruments, observer training and periodic inspection.

2.5. Use of Local Residents

To overcome the problem of staffing observing stations in the Arctic, every effort should be made to employ and train local residents who are qualified for this work.

2.6. Establishment of New Stations

Central N.W.T. - At the present time there is a major gap in both the hourly and synoptic network in the area between Fort Reliance and Baker Lake. A new observing station is required in this area in the general vicinity of Pelly Lake or Dubawnt Lake.

Cowper Point - Present planning calls for the establishment of an observing station at Cowper Point in 1975. This date should be advanced to 1972.

Bathurst Inlet - Present planning calls for an observing station in the period 1977-81. This should be advanced to 1973.

2.7. Upper Air Observations

Although stations are more widely spaced than in Southern Canada, the upper air network meets necessary standards with one possible exception. The closing of the station at Clyde River, on the northeast coast of Baffin Island, has left a major gap in this area. This station was closed because the local site was unsuitable and cost of relocating was very large ($1,500,000).

2.8. Satellite Observations

The use of meteorological satellites could afford a valuable means of supplementing the sparse observing network in the Arctic. While present meteorological satellite observations in the visible spectrum would only be available during part of the year, this would be in the period of maximum activity and with the later introduction of infra-red observations would be available all year.

The provision of a satellite readout station at Resolute Bay would provide a valuable supplement to present limited weather information. Such information could be relayed to more southerly Weather Offices, such as Inuvik or Frobisher, by means of the improved facsimile circuits suggested below.

6.5. Communications

Requirement

Communications should be adequate to provide all the necessary data to points where it is required within acceptable time delays. Reserve capacity should be available to allow for transmission of information on a request-reply basis.

Deficiencies in Current Services

(1) Arctic Islands - There has been a major improvement in communications in the Arctic Islands (Joint Arctic Weather Stations) since completion of the radio-teletype network in 1969.

(2) Tuktoyaktuk to Inuvik - There is a continuous requirement for exchange of weather information between these two points. Although only 80 miles apart Tuktoyaktuk observations from the Dewline site must be sent by R/T to Cape Parry, then by meteorological circuits to Edmonton and then to Inuvik while observations from the Polar Continental Shelf group must be phoned to Inuvik. Frequent delays result. If a program of hourly observations by contract is undertaken at Tuktoyaktuk it is proposed that this location be linked to Inuvik by radio-teletype.

(3) Facsimile at Inuvik - The proposal to raise the status of Inuvik to a Weather Office requires that this office receive the maps and charts carried on the National Facsimile Circuit. An attempt to receive these by radio-facsimile from Edmonton during the first half of 1970 has not been successful. For satisfactory reception two proposals have been made:

(i) Inuvik should be provided with landline facsimile connection to Yellowknife.

(ii) Facsimile transmissions should be carried by microwave relay to Lady Franklin then east and west along the DEW line. This would permit LF broadcast from Cambridge Bay to Resolute and a corresponding improvement in facsimile reception at that point and at Frobisher Bay.

Subject to further confirmation of its technical and economic feasibility, the second suggestion would provide improved reception at both Inuvik, Resolute Bay and Frobisher at a marginal increase in cost over (i) and would therefore be the preferred solution.

6.6. Research

Although there is a continuing research on general meteorological problems both within the CMS and the universities, there is little research directed toward purely Arctic problems. To provide a greater understanding of weather problems peculiar to the Arctic and of their effect on man and his environment, there is a requirement for both applied and operational research. Some examples of this requirement are:

(1) Research on weather factors peculiar to the Arctic such as "Arctic Whiteout" or ice fog.

(2) Research on the environmental effects of human activities in the Arctic.

(3) Research on the local climate of locations planned for new airport development.

(4) Research on methods and procedures for provision of wind-wave forecasts for Arctic off-shore drilling.

7. PROPOSALS

In order to provide the new and improved services required by the increasing activity in the Arctic, it is proposed that the Canadian Meteorological Service should:

(1) Expand its present forecasting program to cover new areas, new locations and new activities in the Arctic and to cover extended periods of time.

(2) Effect a major increase in the number of weather observing stations in the Arctic, including those reporting climatological data, hourly aviation weather data and those required for the basic synoptic network.

(3) Develop a reliable and accurate automatic weather observing equipment capable of operating for long periods at unmanned sites in the Arctic.

(4) Increase technical staff for presentation functions to meet the large increases in demand at principal Arctic airports.

(5) Provide for an increase in the frequency of weather observations at certain existing stations.

(6) Improve communication facilities to ensure that all necessary data or information is handled with a high degree of speed, accuracy and reliability.

(7) Provide for increased research on Arctic weather or climate and its effects on activities and the environment in the Arctic.

8. TIMING CONSIDERATIONS

The proposed program must be phased over several years - possibly 1971-74. Expansion of present programs - either in observing, forecasting or climatology - is limited by availability of present staff and facilities while certain steps in the proposed program are prerequisite to others - e.g. automatic weather stations must be further developed before further expansion in the climatological network. In other cases expansion of services is dependent on future development of the facility or activity they will serve.

9. FINANCIAL CONSIDERATIONS

Extended over a period from 1971 to 1974, a rough estimate of the above program - excluding the upper air station at Clyde River - is as follows:

Year	Capital	Increases in Operation and Maintenance
1971-72	100,000	250,000
1972-73	130,000	190,000
1973-74	120,000	60,000

The cost of re-establishing and re-equipping Clyde River are estimated at $1,500,000.

10. CONCLUSION

The increasing level of activity throughout the Arctic has created demands for more meteorological services than are possible with existing knowledge and facilities. The satisfaction of these demands will necessitate:

(1) A substantial increase in meteorological data from the entire Arctic area.

(2) Improved communications for the collection of meteorological data and distribution of meteorological information to users.

(3) A modest expansion of the existing forecasting and presentation services.

(4) Increased capability, through research and development work, to provide meteorological consultation services.

AIR TRANSPORTATION IN THE HIGH ARCTIC

BY: W.W. PHIPPS
PRESIDENT, ATLAS AVIATION LTD.

This paper proposes to deal briefly with the problems relating to air operations in the High Arctic.

There has been a dramatic increase in the demands for air transport over the past five or six years and there is every indication that this demand will increase at an accelerated rate.

Air carriers are faced with many operational problems which do not exist in southern latitudes for example:

Magnetic compass is unreliable

Vast distances between facilities

Extreme climatical conditions

Lack of weather reporting stations

Communication blackouts

Inadequate and obsolete radio aids to navigation

There are few personnel available with sufficient specialized arctic experience to cope with problems peculiar to the area.

As a consequence there is an immediate and urgent need to up-grade facilities and to create economic and physical environment which will attract the type of individual need in the development of air services.

AIRSTRIPS AND AIRPORTS

Up until 1963 the arctic settlements could expect as few as four aircraft a year and there were long periods during freeze up, break up and dark periods when they were completely isolated. Now settlements such as Pond Inlet and Arctic Bay are receiving one hundred and twenty-five flights per year on a twelve months basis.

Land strips have been constructed at most settlements by local residents with very limited funds and equipment but Lake Harbour, Port Burwell and Belcher Islands have none. Although many airstrips are inadequate priority appears to be given to improving airstrips at settlements which already have adequate strips for STOL aircraft.

Suggestions:

1. That the regulations governing specifications for airstrips be amended for STOL aircraft.
2. That top priority be given to providing suitable STOL airstrips at all settlements before improving existing adequate strips.
3. That airstrips be properly lighted and include obstruction lighting.
4. That Resolute Bay which is the main supply base

for the Arctic Islands be lengthened and paved to accommodate heavy jet traffic.

RADIO AIDS TO NAVIGATION

The present radio aids to navigation system consists of a wide spread network of frequency non-directional beacons but these should only be used as a secondary aid. They can be rendered unreliable by night effect - coastal effect - terrain - atmospherics - precipitation static - wave probagation etc. It is not uncommon for the effective range of a low frequency beacon to be reduced to twenty or thirty miles.

Navigation difficulties are accentuated by factors such as:

Magnetic compass unreliability

Distances between facilities

Inaccuracy of weather forcasting due to insufficient reporting stations

Astro shots have to be used for heading checks which are frequently not possible due to cloud cover.

With present facilities it is not possible to accurately monitor flight progress and gross errors can occur in navigation due to wind changes or gyro precession.

Suggestions:

The present network of low frequency radio beacons should be augmented by a similar network of VOR - DME installations. Such a network would not provide complete coverage of the region but it would provide for the positive monitoring of flight progress for 50 to 75% of the time.

APPROACH AIDS

In the High Arctic low frequency beacons are the only approach aids available with the exception of Frobisher Bay which is equipped with ILS.

Extreme weather conditions such as fog, white-out, low stratus, snow and blowing snow conditions are most prevalent in the Arctic Islands, and weather limits for landings from beacon approaches are too high to cope with these conditions.

There are approximately fourteen wrecked aircraft around Resolute Bay many of which crashed while attempting to land in poor weather without a precision approach system. The cost of almost any one of these would be equal to the cost of an ILS system.

Suggestions:

The immediate installation of ILS systems at Resolute Bay and Cambridge Bay.

PERSONNEL

By the nature of Arctic operations the highest quality and most experienced personnel are required to carry on a safe and efficient operation. There are relatively few people with arctic experience and few who are willing to accept employment in the Arctic. Extreme climatical conditions, lack of housing, lack of social life and isolation are a few of the deterrents.

The only lever an operator has to attract personnel is by paying extremely high salaries. Even this has a limited effect because of the resultant higher income tax.

The acquisition of sufficient qualified personnel to staff a rapidly expanding industry is and will be one of the most formidable problems air carriers have to face.

SUGGESTED GOVERNMENT ASSISTANCE

1. Income tax concessions to people who are prepared to take up residence in the high arctic for an extended period of time, for example, the Danish

Government waive all income tax to people who move to Greenland for a minimum period of two years.

2. One hundred percent tax write-off should be allowed on all construction in the first year.
3. Land should be made available on a long term basis at a nominal fee.
4. In situations where the Government is selling services to the public, such as power, water, food and accommodation, this should be done at the true additional cost. For example, at Resolute Bay, the Government is responsible for the weather stations, the settlements, etc. It would have to have an establishment at Resolute regardless of whether there was a single member of the public at Resolute or not. But the charges to the public appear to be based on the theory that the operation is solely for the benefit of the public at Resolute. Consequently all charges are so excessive that they discourage the development of the area.
5. The Government presently has a scheme to provide long term low interest loans and quick write-offs to companies who are prepared to establish industry

in the so-called "depredded areas" in the South. It would be reasonable for the Government to assist companies in a similar manner who are prepared to establish a business in the High Arctic.

6. Government agencies who have a requirement for air transport in the High Arctic should give priority to air carriers established in the area.
7. Ministry of Transport officials appear to be preoccupied with problems in the South and should they appoint a Committee who would be primarily concerned with Arctic problems, it would provide much closer liaison between Ministry of Transport and arctic operators.

ARCTIC AVIATION FACILITIES

BY: GORDON L. BARTSCH
PRESIDENT, GREAT NORTHERN AIRWAYS LTD.

It is not often that an Aviation Company working in an area has an opportunity to voice opinions and ideas for the development of that area and from such a standing start as we have in this particular case. I would like to thank those concerned for this opportunity and would like to express my appreciation at being invited to participate in this Conference.

This afternoon we have heard four Papers dealing with Meteorological Services, Navigation Aids and Airport Facilities of the Canadian Arctic, and I sincerely hope that my contribution combined with the Papers you have heard, will help to develop the facilities in a proper and orderly fashion, and in a manner which will benefit the Industry in the quickest and most economical practical manner.

These three key requirements, their planning and their implementation, are of the utmost importance to the economical and commercial development of what we have so often heard in the last few months as - "Canada's Last Frontier". These services should be planned with the same consideration and foresight as the

planning that went into the development of Canada's first Trans-Continental Railroad, and I feel for the same reasons. For these Airports and Airways will contribute to the Canadian Arctic, what the C.P.R. did to support Confederation. Government criteria and standards that are now being used as a yardstick for Airport expansion and the development of new facilities, have to be forgotten for they won't work in this particular phase of Arctic development.

In the past, expansion was justified on the number of passengers carried, tons and passengers per mile. We do not have that statistical data, nor do we have time to wait for its development, but must take positive action in a bold manner NOW.

In the past I feel that the development of Airports and the pattern of airways has been left to chance and casual happenings without regard to proper economic planning or overall concept. The Air Industry has suffered by this lack of planning and the result has been inefficiencies which in turn increases costs; costs which must be either absorbed by the Operators or passed on to the user, whenever possible. The result is that the services provided in many cases cost too much, or the Operator does not make any money, which has probably been more the case. In any event either result is unsatisfactory.

We now have an opportunity before us to do something right, and I sincerely hope that the Government, with the help of our Industry, will take advantage of this opportunity and provide a properly-constructed network of Aids.

I feel that for the sake of the Air Industry, an Industry now facing spiralling costs and a return on investment which drives any prudent investor away, that we must have a safe and adequate system of Navigation, Air Routes, Airports and Meteorological information, before we face the harshness of Arctic flying of the scale which lies ahead. For, without proper planning, there could be disastrous financial results both for the Aviation Industry and those Industries we are attempting to serve.

It is most apparent to those involved that all phases of activity are going to escalate very rapidly over the next few years, starting this Winter. There has been much discussion within the Oil Industry and between the Canadian and American Governments on present oil reserves and future requirements, which will ensure a high degree of oil activities in the Arctic, and it is for these reasons that we must throw away the old guide-lines for development, and provide the Aids and Services before the statistics are built - and not after.

In short, we must have more Airports north of the Arctic Circle,

and these Airports must be surrounded with Navigational Aids for landing and for enroute navigation. These Airports must also be provided with up-to-date meteorological services and information.

Up until now, flying in the Arctic has been approached with a great deal of caution, and by only the most experienced people - flying for the most part, with good equipment.

We have been extremely fortunate that the losses of life has indeed been small. In fact, I think I can safely say there has been no loss of life in fixed-wing aircraft related to oil exploration; and damage to aircraft not alarming in view of the primitive conditions and the lack of facilities and information available to the pilots. Until two private V.O.R. Stations were recently installed, the only advantage the pilots have had over the pioneers of 40 years ago, is that he is better trained, and his equipment is superior.

BUT it is still "seat of the pants" navigation to get from A to B as was in the days of WOP MAY, and this is no credit to either a Government or an Industry, in an age when they can put a man on the moon.

I don't think we can continue to be so fortunate in the areas of accidents, unless we take immediate steps to improve all forms of Aids. We shall not be fortunate for the simple reason that

familiarity breeds contempt. Those who are inexperienced will begin to invade the Arctic in private aircraft, having lost their fears of Arctic flying in the local airport coffee shops. Also there is a danger of those experienced pilots flying in the area, and not having had problems tending to take a more casual attitude and finding themselves in trouble. Our accident rate could climb alarmingly along with the loss of life, and equipment, placing a heavy cost burden for everyone. The costs appear in many forms, such as -

The cost of one search for a lost aircraft could exceed the capital cost requirement for installing a complete Airways Navigational System that would cover the whole Arctic.

Insurance rates could become terrifying and for a lesson in that we need only look west to Alaska's Prudhoe Bay area, their loss record and insurance rates.

Costs due to loss of aircraft can be in the form of -- Deductibles, and loss of revenue for the Operator.

These costs not only affect the Aviation Industry, but those Industries which we are attempting to serve must wait until either the weather clears so that landing can be made without Aids, or additional aircraft are made available to replace those banged up while attempting to do the job in poor weather without proper

assistance.

The most expensive thing that we can do now is NOTHING !

I am not suggesting that we need paved airports on every Island complete with Instrument Landing System, and Approach Radar although it would be nice ! I know that with to-days's economical restraints it is hard to justify expenditure when the needs are not pressingly apparent. However, I think we are faced with a situation where expenditures must be made in anticipation of requirements.

There were many critics at the time of construction of INUVIK and of the $100-million that was being spent. However, this is the kind of thinking and type of decision that is once again required, for if INUVIK had not been built, development of the Oil Industry in the Mackenzie Delta area would be seriously impaired and the cost prohibitive but for the largest Operator. Inuvik now is at the point where private enterprise is able to establish itself and carry on the growth of that town. I feel it is the Government's roll to pave the way into these "frontier" areas in order to establish a plateau from which private enterprise may build.

To start with, a second major airport is required urgently; one that will be suitable as an alternate for Resolute Bay, and vice versa, but far enough away so as to be in a different weather

pattern and to basically serve an adjoining area.

Melville Island is a possible location. It is distant enough to be out of a common weather pattern with Resolute Bay, but close enough to provide an alternate airport without requiring large fuel reserves. A site further than 200 to 250 miles away would tend to defeat this purpose. It should be an all-season, all-weather airport with two runways. I suggest two runways as any single-strip airport is usually designed to maximize the cross-wind component. With two equal runways at 90 degrees to each other, I defy the Airport planners to get any one runway more than 45 degrees out of prevailing wind.

In order to justify the expense involved in the development of a second Airport, consideration could be given to the establishment of a Military Air Base in the High Arctic. By having the Military's presence in the Arctic, the Sovereignty question would be partially answered. It would be an excellent training and testing ground for new equipment and procedures, and a very important aspect would be a Search and Rescue Group, close to an area where when needed would be needed very quickly. I would suggest here that their usefulness would not be looking for downed aircraft only, but likely as exploration increases, for locating lost ground equipment and vehicles.

At this second Airport, I would suggest that a hangar complex be constructed, that would satisfy both the Military's requirements and that of Civil Aviation. It could consist of aircraft storage, maintenance shops, personnel housing, together with hotel facilities, restaurant and entertainment centres all on a commercial basis and available to the public.

Private enterprise cannot be expected to develop such an undertaking at this time, but once established, private enterprise could be expected to develop and grow.

Having facilities of this nature available and provided at a fair and reasonable cost, would have a cost stabilising tendency, for example -
Aircraft maintenance and standard checks, and overhauls could be carried out in the Arctic without the necessity of either expensive ferry flights for minor repairs, or the transportation of many components for overhaul.

With the development of a second Airport, the problem of a reliable alternate would be solved, providing modern landing Aids such as Instrument Landing System, and Precision Approach Radar are made available. In addition Resolute Bay should be up-graded in all aspects of Navigational Equipment and Landing Aids. Had this equipment been available in the past, many of what are now

statistics would still be flying.

When you look at a radio navigation chart covering that area of the Canadian Arctic in which the oil exploration and drilling programmes are being carried out, you can see what I refer to when I say "primitive in navigational aids". In an area North of the DEW Line and equal to approximately one-quarter of the total land mass of Canada, consisting for the most part of featureless terrain and unpredictable weather, there are something like NINE Non-Directional Beacons, some of them noted as being "SUBJECT TO UN-SCHEDULED OUTAGES".

This is not a comforting feeling, a feeling which can last for six months during the night.

The only airway North of the DEW Line is in the Eastern Arctic, running from the DEW Line site of DEWAR LAKES via CAPE CHRISTIAN to the U.S. Air Base at Thule, Greenland, where they have every landing aid conceivable including a canteen, which in some cases has helped the odd pilot complete a dirty trip, as much as a G.C.A.

Up to this point my suggestions have been reasonably modest - Only one Airport and possibly the creation of Canada's first domed-city with controlled environment, but NOW comes the big plan !

My next suggestion is one of a little more immediate importance and urgency, and one that could, with the right support, be in operation in six months.

I feel that the most important and urgent requirement is the establishment of a triangular network of airways encompassing Inuvik on the West to Hall Beach on the East and North, as far as ALERT. This would cover the area of activity now devoid of published enroute Aids.

I am aware that private approved routes exist over much of this area, but feel that permanent and published airways covering all areas, are now required.

A dollar figure as low as $720,000 could provide an acceptable navigation system covering the entire Arctic Islands, that is far superior to what we now have - which is NOTHING.

By installing V.O.R. with D.M.E. capability at NINE locations, we could accomplish this minimum requirement. These installations would be made at:

INUVIK
SACHS HARBOUR
MOULD BAY
ISAACHSEN
EUREKA
ALERT
RESOLUTE BAY
CAMBRIDGE BAY
HALL BEACH

and with the addition of two Private facilities, one operated by Panarctic at Rae Point on Melville Island, and the other at Johnson Point, a facility operated by Elf Oil on Banks Island, for a total of eleven locations; the entire area could be adequately covered.

This would be money well spent and money that should be spent immediately. Six months from now could see the system installed and in operation. It would take some doing, but it is the kind of "doing" that built the West, and it is the kind of "doing" that will have to be displayed to build the North.

Now, I can hear all the arguments against a rapid, Navigational System installation. I can hear cries of horror from the Ministry of Transport airways officials, that a location cost of $60,000 for a VOR/DME Installation, would have to be junk, and that it probably would not meet standards. My answer is - that the Units in operation now in the Arctic are on the initiative of private enterprise, they work very well, and they are a lot better than NOTHING. Low level reception on the Units is approximately 60 miles; and at 25,000 feet - 160 nautical miles. Their cost is $30,000 for the V.O.R. complete, and another $30,000 for a D.M.E. capability. Now with a D.M.E. capability, the pilot has valuable information in an area where radar surveillance is non-existent. The pilot can plan his descent properly and for turbine equipment

it enables the pilot to remain at altitude and to conserve his fuel, which can be a very critical factor in any aircraft - and more particularly so in the Arctic.

Accurate upper wind computation is another D.M.E. benefit of prime importance, especially in an area which is subjected to high velocity and erratic wind patterns. By having D.M.E. at all Stations, Operators would have an additional feature available to them that I think should be explored. For as little as $6,000 per aircraft, an Operator can install computing equipment in his aircraft that makes possible a system of Area Navigation using the existing VOR/DME Stations for off-route flying and/or letdowns.

This is known as "R/NAV". Very simply this system, by the use of an airborne computer, permits a pilot to place a VOR Station in any location that he wants, permitting accurate navigation and letdowns where in fact, a facility DOES NOT EXIST. This is an approved procedure in the States, and one I think should also be explored to the fullest for use in the Canadian Arctic.

This may be the time to throw in another suggestion for the Inspectors of the Ministry of Transport to consider, and that is -- Maybe there should be some form of clearance or a licence endorsement required before a pilot is allowed to venture North of the DEW Line. This could be the requirement on an Instrument

Rating, or a special Arctic Navigation Course, but I do think some thought should be given to control of flying in the Arctic Islands. This would perhaps discourage, or even eliminate the inexperienced and/or foolhardy pilot from venturing into an area beyond his capabilities.

The third point, which I have not touched upon, is the collection and distribution of Meteorological and other information pertaining to the safe conduct of flying operations in the Arctic. Those persons now engaged in Meteorological work in the Arctic DEW Line sites of, for example, Resolute Bay, are in the main, quite dedicated and conscientious in the carrying out of their duties. The facilities which they have to work with are inadequate. There have been cases in the past of conflicting reports and forecasts, and at times a complete lack of information.

I would suggest that a full study be conducted and to assimilate all meteorological information with particular emphasis being placed on that available from the U.S. Weather Bureau in Alaska, and this information made freely available throughout the Canadian Weather Reporting System.

All information gathered at DEW Line sites should be broadcast in a normal manner and weather sequences made more readily available to pilots in the area. As a quick example, weather information

at TUK is not readily available to pilots at Inuvik and if requested, has to be relayed via Montreal or Colorado Springs and then back to Inuvik - a rather long way to span 88 miles from Tuktoyaktuk. Consequently, pilots take off without the information required and request it by radio, which is then readily given. Further, all the proposed VOR sites which I spoke of earlier, would have a voice capability and weather information could be passed on in this manner as well.

I feel that with the development of Airport and Navigational Aids the matter of the establishing of additional weather stations and the problems of relaying weather sequences, would not be too difficult.

In summary, we have an urgent requirement for the development and establishment of navigational aids, airports and meteorological information that must, through bold planning, be established immediately in order to develop a safe and orderly system of air transportation, so that we, as an Industry, can effectively carry out our assigned role in the development of the Canadian Arctic.

VOLUME 2

SECTION 2 - EASTERN MARINE RE-SUPPLY
(INCLUDING HEAVY
HELICOPTER OPERATIONS

CHAIRMAN: G. Jacobsen

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R. Currie

B. N. Malott

"A wonderful bird is the pelican
His beak can hold more than his belican.
He can take in his beak
Food enough for a week,
But I'm damned if I see why the helican".

Dixon Merritt

EAST ARCTIC MARINE RESUPPLY

BY: A.H.G. STORRS
DIRECTOR MARINE OPERATIONS BRANCH

For the purpose of this paper, Marine Resupply is taken to mean the inward movement of cargo by sea to destinations in the eastern part of the Canadian Arctic or sub-Arctic.

In this context the Eastern Arctic is not so much a geographical division as that part of the Arctic supplied by shipping from the eastward. Indeed resupply from the eastward overlaps longitudinally with resupply from the westward. This came about partly because of the distances involved from procurement to destination and related economics, but also because of the distribution of ice in the central Arctic. This is still a considerable barrier, but the discovery of navigational depths in Victoria Strait and the availability of ships better able to cope with ice in the Franklin Strait route could change the traditional pattern.

EVOLUTION

The evolution of marine activity in the Arctic has followed four lines of development :

1) The exploration and fur trading activity.
2) Non-military government activity.
3) Military government activity.
4) Commercial activity.

These activities have tended to overlap, although one of them has usually been predominant.

Exploration and fur-trading activities originated in the sixteenth and seventeenth centuries, when people like Hudson and Frobisher made the first probes into the area seeking a passage through the Americas to the Pacific. They were followed by many others interested primarily in the fur trade. The long squabbles between the English and French, the Hudson Bay Company and the Northwest Company was for control of the access to the fur bearing heartland of the continent. Missionary work was also begun. In the early 1900's the pioneering voyages of Bernier and the establishment of the Eastern Arctic Patrol by the voyage of the NEPTUNE led to international acceptance of the Arctic as Canadian territory.

In April of 1929, the railroad finally reached the port of Churchill and in September, 1931, the elevator and wharf facilities were completed and the port opened for business. Now the port handles over 700,000 tons of cargo annually, 95% of which is wheat, and most of the remainder, petroleum products for consumption in the Hudson Bay area. This trade has given little impetus to Arctic development as the Hudson Bay is primarily a shipping route for grain grown elsewhere. At this time, Federal Government activity consisted mainly of administration and policing and looking after the indigenous populations, some survey and exploration work, and keeping an eye on things in general.

The first strategic interest in the Arctic developed during World War II. The huge demand of the European Theatre for aircraft of all kinds created staging routes through the Eastern Arctic, Greenland and Iceland to England. The need for improved weather data and communications in the Eastern Arctic led to the establishment of a few meteorological and communications bases. After the war, much of this military activity was allowed to lapse and tonnage requirements fell off to little more than their pre-war figures.

In 1948, Canada and the United States signed the Joint Arctic Weather Station agreement by which five weather stations were established in the High Arctic, to be jointly operated but supplied by the United States. The American sealift was carried out as a military operation and old Arctic hands remember that it was quite a spectacular undertaking. In those days, the Americans had the large icebreakers, with their Glacier and Wind class, and we did not. In 1953, Canada assumed responsibility for re-supplying these stations, under agreement with the United States Air Force.

In the late forties and early fifties, the realpolitick of the strategic bomber and the nuclear bomb arrived in the Arctic. In 1955, the Distant Early Warning Line agreement was signed between Canada and the United States, establishing a line of aircraft detection stations across Arctic Canada roughly along Latitude 65 to supplement the Mid Canada and

Pine Tree lines. Construction began in 1956 when some fifty chartered cargo ships carried over 61,000 tons of supplies to 75 existing and planned sites. Much else was delivered by air. Although this was an American operation, Canada participated by sending north the icebreakers d'IBERVILLE, N.B.McLEAN, SAUREL, EDWARD CONRWALLIS, the patrol ships C.D.HOWE, two LCT's, MINK and MARMOT, fourteen LCM's, fourteen barges and two tugs. In 1958, Canada assumed responsibility for the whole re-supply operation and by Order-in-Council P.C. 1959-38/304, the then Department of Transport was given the task of co-ordinating "the assembly, transportation, and delivering of supplies for all Government departments to the Eastern and Western Arctic." Responsibility for the latter area was later delegated to the Northern Transportation Company.

Although the Ministry's function was primarily one of co-ordination, nevertheless it inevitably became involved in actual operating for several good reasons. For example, the normal port facilities for the reception and handling of cargo were completely absent in the Arctic. Cargo had to be landed "over the beach" and it was necessary to turn to military equipment and methods. No existing stevedoring companies in Canada were equipped for this kind of operating and none could justify the very heavy capital investment for such a short and specialized annual operation. Inevitably the Ministry had to procure and provide much of the equipment and services needed, large and small landing craft, barges, maintenance facilities, operating crews and administrative services.

Furtheremore, what little resupply had been done in the past had been done in Ministry of Transport ships and there was therefore a natural tendency to continue the practice to the extent that their capacity allowed. However, the circumstances of the development of this traffic and the geographic conditions were very different from those of the west and there was not the same pressure or need to create a crown corporation or a direct government owned and operated shipping service. Commercial vessels able to do most of the work were available and government ships were used only for the work that commercial freighters could not do or where relatively small

parcels of freight could be carried incidentally to an icebreaker's other operations.

PRESENT SITUATION

Present shipping activities in the Arctic comprise government organized operations for federal and territorial government purposes, non-government operations in support of mineral exploration, general trading operations such as for the Hudson Bay Company. There is also a considerable trade involving some 40 to 50 ships each summer through Hudson Strait to Churchill, but this is almost wholly for the outward shipment of bulk grain and therefore outside the scope of this paper.

Government Organized Operations

Military

The present permanent military presence in the Arctic is related primarily to the air defence of North America, which is a joint Canadian-United States activity. There is a considerable number of station concerned with early warning and aircraft control requiring the supply of operating and maintenance materials. The bulk of this is shipped by sea annually, some directly to the sites concerned, others to central sites from which it is re-distributed by air. The toal sealift cargo is approximately 35,700 tons to the Eastern Arctic sites, of which about 90% or so is POL.

Non-Military

The Federal and Territorial Government responsibility for general government services in the Arctic includes such matters as welfare, education, medical services, policing, judicial services and general administration. Over recent years government activity in all spheres has increased involving larger numbers of people and consequent increases in the amount of material and supplies to be shipped. Some of this stems from the growing concern with the indigenous population and some from the general increase in mineral exploration. In addition, there is growing activity in scientific

investigation and the collection of scientific data - much of it by Federal agencies.

The Ministry has up to now been responsible for organizing the resupply by sea for all these activities. Most of the cargo involved is destined for the Department of Indian Affairs & Northern Development's Arctic activities. A total of some 25,000 tons of supplies is shipped, of which 75% is POL. Of this 13,000 tons goes to Resolute; 8,000 tons to Frobisher, and 3,500 tons to posts or settlements in the Keewatin area and the rest to Hudson Bay.

The average annual total shipment into the Arctic undertaken by the Ministry therefore amounts to about 61,000 tons. Of this total 40,000 is loaded in Montreal and Quebec, 8,000 in Goose Bay, 12,000 tons in Churchill and the remainder at Dartmouth and other maritime ports. In addition to this cargo, there is a fair amount of lateral movement between Arctic ports and a certain amount of outward cargo to an annual total in the order of 110,000 tons.

The Shipping Operation

The method by which this is undertaken today is primarily through the use of non-government shipping. Some vessels are chartered outright where this is justified by the quantity of the cargo to be moved, and space is rented in other vessels. This year MOT chartered eight vessels and shipped cargo in ten others. Small quantities of north-bound cargo are also carried in the northern supply vessels and icebreakers which must go north anyway. However, the trend over the years is for more and more cargo to be moved by commercial vessels as suitable ice-strengthened vessels become available for charter.

By the middle of July icebreakers are in the north activating the aids to navigation, dropping off some cargo, and preparing for the arrival of the Baffin, Resolute and High Arctic convoys, which they support. The Hudson Bay-bound ships leave in early July, supplying the Pacer Pine sites

en route. In early August the Resolute and High Arctic convoys leave for the North. In late July, ships bound for the Pacer DEW sites head north, accompanied by the NARWHAL. After completing the Baffin sites, the Pacer Basin sites in Foxe Basin are supplied. Generally, one MOT Northern Supply Vessel supports the Baffin-Foxe operation, a second works in Hudson Strait and Foxe Basin, and the other two supply Hudson Bay settlements. Their primary task is to shuttle oil between the tankers and the beaches. Much of the oil for Hudson Bay ports is loaded in Churchill and shuttled to the settlements. The Ministry sealift is usually complete by early October. The icebreakers escort the cargo vessels out to open water, assist the last of the grain ships out of Hudson Bay, complete their survey and research work, de-activate the aids to navigation and are usually clear of the Arctic by the end of October.

Over the years, the Ministry has been able to develop a hastily organized, ad hoc system into an almost routine operation. As there has been virtually no harbour development over the years, it is still necessary for the Ministry to provide freight handling services. There are now used in the government sealift, four northern supply vessels - principally for transferring oil at sites where the tanker cannot get close enough - 48 landing craft, 20 dumb barges and the CCGS NARWHAL, an accommodation ship for stevedores and barge crews. The Ministry has thus acquired the plant, the organization, and the expertise to carry out the operation in its present form.

The surface lighter is the weakest link, having next to no sea-keeping or icebreaking capability, so that rough seas or unfavourable ice conditions simply bring the operation to a halt until conditions improve. The Ministry's northern supply vessels are also unable to perform effectively in some conditions. These vessels are obsolete and are really too slow, at 8 knots, and underpowered, at 1,300 h.p. for Arctic work. They are retained only because of the lack of other suitable craft for the shallow water coastal work.

Non-Government Operations

In recent years there has been a very great growth of traffic into the high Arctic for the support of mineral exploration by commercial companies granted licences. By far the greater part of this is carried in ships chartered independently by the exploration companies, or in some cases owned by them.

This year there were at least twenty-three commercial cargo vessels operating in the Arctic, exclusive of grain ships and ships under charter to the Ministry. Almost 40,000 tons of fuel oil was shipped to oil exloration activity by seven tankers. Four ships delivered general cargo to oil drilling sites and a fifth delivered supplies to mineral exploration activities in Hudson Bay and the Baffin coast. The remainder were engaged in general trading carrying cargo on a rate per ton basis to Government and commercial activities in Goose Bay and ports in the Eastern Arctic and Hudson Bay.

With the Hudson Bay Company delivering approximately 3,000 tons of cargo, a total of 30,000 tons of general cargo and 40,000 tons of fuel oil was transported for commercial operators. For the first time commercial operations accounted for more cargo than the Ministry.

In addition some 5,200 tons of general cargo was flown into the Eastern Arctic by commercial carriers during the year giving a total for all operations of 136,000 tons.

Government Supporting Operations

The Government provides the normal services and facilities for support and assistance to navigation in the Arctic in the same way as in other Canadian waters. These comprise meteorological services, aids to navigation (though at present very limited in the Arctic), hydrographic charts, search and rescue services and the same sort of supporting services for ice navigation that operate in the Gulf in winter consisting of ice reconnaissance, forecast and information, ice operations offices for direct

advice and individual information to ships, icebreaker support when necessary.

Conclusion

The present status of Arctic resupply is the result of empirical evolution rather than organized planning, and indeed it is only recently that guiding principles are beginning to take shape. Nevertheless, it is difficult to find serious fault with the process in the context of the events, requirements, attitudes, national policies and state of knowledge that have shaped its evolution.

The method of operation achieves what needs to be done. There are certainly flaws but these, we suggest, are of degree rather than major substance. Most are minor ones related to changes in operating procedures or regulatory matters that are already either in train or under consideration and no major changes in policy or organization are needed to maintain effectiveness under present conditions. It is important, rather, to consider the effect of future developments on transportation requirements.

FUTURE REQUIREMENT FOR RESUPPLY

Government Operations

Military

The original warning and control network in the Arctic was designed as part of the defence system against attack by manned bombers across the Pole. The missile is now replacing the bomber and the transition could well involve changes in the scope of permanent military installations in the Arctic, though it is not yet clear what affect this might have on the requirement for resupply tonnage.

Non-Military

If mineral exploration and development activity should increase appreciably some expansion in government services might be expected, though

at present it does not seem that this would be great. Additionally there could be some increase in scientific activity, particularly in relation to the environment.

On balance, however, it seems doubtful that changes in government activity of all kinds are likely to generate anyconsiderable or rapid change in resupply requirements that would lead to significant change in the pattern of resupply.

Exploration and Development

Resupply tonnage to support the mineral exploration industry has grown phenomenally in the last few years and this year overtook tonnages for defence and civilian government purposes. The answer to the question of how this will continue is of course the key to estimates of the future demand for resupply. A major strike fairly soon could lead not only to the drilling of development wells, but also for the need for facilities for shipping oil outward. Continued failure to find oil in development quantities could conceivably lead to a reduction in exploration interest. The possible spread between the two in requirement for materials and supplies is so great that any attempt to forecast actual tonnages is little more than speculation.

Nevertheless, some projections are of interest. The drilling of a well requires about 1,200 tons of supplies. If fuel is included, the total is about 2,000 tons. Using these figures and the hoped-for rate of exploration drilling, it is possible that resupply tonnage for oil exploration work alone could reach over 350,000 tons a year in a very few years. This is for the whole of the Arctic and the distribution between east and west is extremely difficult to estimate.

The probability of finding further Prudhoe-type discoveries throughout the Canadian north is fairly high. Such discoveries could add substantially to the inward tonnages. There would be required supplies for drilling of development wells, support facilities, pipelines, pumping

installations, loading sites, gas liquidification plants, etc. Assuming a major oil discovery in the next year or so, the supplies required for both production and continuing exploration could amount to a million tons a year after ten years.

In the field of minerals other than oil, there are several areas known to have reasonable ore potential, such as Baffin Island iron, Melville Peninsula iron, Strathcona Sound lead and zinc and Douglas Harbour nickel. It is known that the ore bodies are of a size to warrant development but the problems of the economics of production and transportation to market under the severe environmental conditions have yet to be solved. Nevertheless, the start of development within a decade seems probable rather than possible though the pace that this would take and the tonnage requirements to bring the mines into operation and maintain them in operation thereafter are difficult to judge.

PATTERN OF FUTURE RESUPPLY

The Nature of the Arctic

At the present time the volume of surface marine transportation in the Arctic is still such that it can be confined to the short open season between the latter part of July and October. It is also on the whole limited to the easier parts of the eastern Arctic - Foxe Basin, the Baffin Coast, Parry Channel as far west as Resolute. Some traffic goes beyond Resolute to Melville Island, but in most years it is possible for suitable ships to find a relatively easy route along the north side of Viscound Melville Sound. There is also a very small amount of traffic through Jones Sound and Norwegian Bay, but here again in most years, the problems are not too severe. In general, however, there is no requirement for movement into the more difficult parts of the Queen Elizabeth Archipelago or Viscount Melville Sound.

It is probably safe to say, therefore, that on balance marine transportation in this limited season and in this limited part of the eastern Arctic is not really much more difficult than operations in the Gulf of St. Lawrence in the winter. Certainly, there are differences but they are more in degree than in substance. For instance, navigators in the Arctic in summer have the iceberg infestation of Baffin Bay to contend with and can encounter the very hard multi-year ice and heavy ridging, but there is also every bit as much open water sailing as in the Gulf, if not more. The Gulf and River St. Lawrence have neither icebergs nor multi-year ice, but they do have fresh water and batture ice which can be just as difficult and ice pressures can be generated in the Gulf that are as hard to contend with as those in the eastern Arctic.

What the Arctic has, as much as anything, is a certain mystique, originating in the days of low-powered wooden vessels. But to compare those conditions with modern ones is analogous to comparing the pioneer flights of the twenties and thirties into the Arctic with the scheduled jet flights we have now. Technology and expertise have made great strides in overcoming the environment, man's conception of it has not. The same mystique used to apply to ice in general, to the extent that when ice began to form in the Gulf of St. Lawrence, marine activity in those waters diminished to negligible proportions. Last year, there were about 1,100 ship movements, involving some 15,000,000 tons of cargo through th Gulf during the winter. The lesson form this is that with the proper ships, the proper expertise, and the proper support, ice can be routinely navigated.

One difference between the Gulf and the Arctic in summer is that in the former, we have made extensive improvements to the environment, while in the latter we have not. In southern areas, the waters have been accurately surveyed and charted; in the Arctic, this is just really getting underway. In the south, we have installed a vast system of navigational aids and controls; in the Arctic, we have deployed a handful of aids along the most important tracks. In the south we have built many large harbours

to provide shelter for shipping, with vast shore facilities for loading; in the north, with the exception of Churchill, we have not.

What the lack of these facilities causes is not so much danger, but delay. If the waters are poorly surveyed, ships will tend to reduce their speed and allow a wider margin for error than they might normally. In some cases such as Baker Lake, the master will be loath to go in at all. This is also true where we have not installed enough aids to allow him to accurately fix his position, or clearly mark the safe passage.

Operation in winter is a very different matter. The present more heavily ice strengthed ships and existing icebreakers could cope with an extended season, say into November for operations in the eastern part of the Parry Channel. But the end of November would perhaps be about the limit. Beyond this is not just a further extension of the present season but entering into a different league - that of Polar operation rather than ice operation of the kind understood hitherto.

There are several gradations of severity of winter navigation in the eastern Arctic - Hudson Strait & Bay, Baffin Bay to Bylot Island, the Parry Channel to Resolute, the waters west of Resolute, are recognizable divisions. There is little doubt that year round navigation of the easiest of these - Hudson Bay & Strait and Baffin Bay - and indeed of the whole route is technically feasible, but the problems of economic viability posed by the type of ships needed are so extensive that the whole question is a study in itself.

Model Alternatives

In terms of direct costs freight transport by air is still a good deal more expensive than sea transport. The situation however is changing quite quickly. The old DC-3 can move three tons of cargo at about 80 cents per ton mile. The Hercules can move 21 tons at 26 cents per ton mile. Freighter versions of the new Jumbos such as the Boeing 747 and the C5A are expected to be able to move 100 tons at about 7 cents per ton mile and it is claimed that the Lockhead 1500 may bring the figure

down to somewhere in the order of 5 cents per ton mile. Compared with this, a 10,000 ton freighter carries cargo at slightly less than one cent per ton mile.

These figures, however, are not very meaningful considered in isolation as there are other elements in the total cost of delivery of an item from the distributor in southern Canada to the consumer in the Arctic and other factors to be considered. A feature of Arctic transportation that is highly favourable to the air carrier is the fact that at present sea transport is confined to the short summer season. The very large inventory that must be maintained to cover a whole year's operation which relies solely on sea transport therefore adds greatly to the total cost of this mode of transport. For high value goods, therefore, the disadvantage of the higher ton mile air cost can disappear very quickly and make it a more favourable mode. In the case of perishables or urgently needed goods, of course, sea transport is not even a starter.

Aircraft have other advantages and provide much more flexibility than ships. There is a significant psychological bonus in that the Arctic worker of the future, who may not be a committed Arcticist prepared to adapt himself to the environment in the way that was formerly necessary and who will expect many of the amenities of his home town standard of living, can be made to feel more in touch and less isolated. The question is a complex one and there is no easy general answer. There is a wide difference in resupply requirements and each must be treated on its own merits as to whether that particular commodity at that particular time to a particular destination is more economically shipped by air or by vessel. While unquestionably more and more freight will be carried by air, the trend for the immediate future is perhaps to a system taking advantage of the best features of both modes - relatively low direct cost and capacity for volume of sea transport and the flexibility of air transport.

Assuming that for the next several years the pattern of sea resupply will be generally similar to the present, i.e., concentrated in the summer navigational season with perhaps some increase over the present

length, it is difficult to see major change in the sizes of ships used - at least so far as government resupply is concerned. This is governed by such factors as the large number of sites to be served in a relatively short time, the sizes of consignments to different sites, limitation of drafts, times that deliveries must be made in order to complete work needed before the winter, etc. An exception might be in tankers where the increasing volume of oil being shipped north could change this view as greater quantities go to individual sites. It is tempting to consider the use of a smaller number of much larger vessels but for the present requirement it is doubtful if these would provide the flexibility that is needed, though extensive use of the Skycrane helicopter for discharging dry cargo could change this situation.

An interesting proposal that has been made rests on the principle of very greatly extended operation rather than trying to fit everything into the present short navigational season and using one or two highly strengthened vessels to extend the resupply over the best part of the year. No doubt a suitable vessel could be constructed to operate in this way but in order to obtain the necessary power and displacement to operate in the high Arctic late in winter and very early Spring the vessel would be considerably larger than is entirely practical taking into account the constraints mentioned above. Discharging cargo would present problems since obviously barges could not be used during the period of heavy ice. In some places no doubt trucks could be driven alongside the vessel but there are places where the ice movement would make this most difficult. Perhaps the main drawback to the scheme is that the very high cost of such a specialized vessel would almost certainly make the rate per ton higher than the present cost of sea transport to the Arctic, and there would thus be little point to the scheme so long as the volume of cargo allows the sealift to be completed in the summer navigational season.

There should also be considered the extent to which resupply to production sites can be done by the bulk carriers that transport the ore or

oil outwards. Certainly this would reduce costs but on the other hand a major priority with such vessels is quick turn-around and there is a limit to the amount of resupply cargo that can be moved in the time available. Furthermore, the discharging port these vessels might not be satisfactory for loading resupply cargo and a diversion to an intermediate port is unlikely to be acceptable. Undoubtedly some inward cargo will be carried by these vessels and perhaps the most likely one is POL.

One of the main disadvantages of sea transport as done at present lies in the method of transferring the cargo from ship to the customer's store or warehouse at the destination. The present over-the-beach lightering method involving not less than four or five handlings of each piece of freight is not only primitive, but results in serious losses from damage and theft. Studies by the Ministry to investigate possible alternatives to avoid these disadvantages and reduce costs with the object of getting as close as possible to the one stage operation of organized southern ports, led to the conclusion that in the case of non-bulk cargo the heavy lift helicopter appears to be the most efficient unloading equipment available for Arctic conditions. Its real potential lies in the fact that it is in effect a portable container gantry obviating the need for construction of duplicate facilities at each settlement. Trials conducted over two seasons give promise of worth while cost savings.

Using conventional lightering techniques, barges, landing craft, cargo can be unloaded at 6 - 8 tons per hour, environmental factors permitting. Total ship waiting time per ton of cargo is about 45 minutes. This requires 60 - 70 men to operate the vessels lifting gear, barges, stevedoring gear on the beach, trucks, bulldozers and the like. Almost all of these tons of stevedoring and lightering equipment have to be carried on board ship.

In the summer of 1970, five different sites were supplied by the Skycrane system. 2,862 tons of general cargo were landed. This required

532 ship-shore movements totalling 71.01 flying hours, for an average of 40.3 tons per hour. Damage or loss was reduced to ½% of the total. The operation required ten men with a fork lift aboard the ship to assemble the cargo and hook it on to the machine, and 14 more with forklifts at the site ashore to unhook it and sort it. Few of these had any experience with the Skycrane. The Skycrane crews consisted of five pilots and four support staff. Work continued in the face of 30-foot tides, 50 knot winds, fog and ice choked waters, conditions which would halt a normal surface operation.

In sum, to unload this tonnage using the Skycrane, a total of 33 aircrew and cargo handlers (and a few more at one site) required 71 hours. Under the old method, it would have required 477 hours, weather permitting. The Skycrane operation required 17 ship days at the site. Under the old system, about 40 ship days would be required.

For unloading bulk cargo (chiefly petroleum products), ship-shore lightering can be reduced by arranging facilities so that tankers can pump directly into shore storage tanks. In many areas, this can be done by running pipelines to the shore nearest the anchorages and joining them to floating hose from the ship. If proper mooring buoys are installed, an unloading tanker will be more likely to stay at the site in poor weather (or come in the first place), all of which would help to reduce charter time. In some areas, of course, lightering will still be required. However, with better surveying, we should be able to bring tankers closer to the settlements, and find more sheltered anchorages to facilitate fuel transfer.

RELATIONSHIP OF GOVERNMENT POLICY TO RESUPPLY

General government objectives in the Arctic relate principally to the maintenance of sovereignty; the encouragement of economic development; the protection of and improvement in the life of the indigenous population; the protection of the environment.

The objectives of the Ministry are to support these through the provision of an efficient and adequate transportation system, and to this end to provide such way, terminal and vehicular services that cannot or should not be provided by the private or other public sectors. The Ministry is also concerned to ensure that socially and economically viable standards of way, vehicle, terminal and operator performance are maintained and to promote improvement of transportation.

The question to be examined then is how these various functions of Ministerial responsibility in transportation relate to the eastern Arctic resupply.

Way

This is a fairly straightforward matter since the provision of such things as aids to navigation, meteorological services, ice support services, radio communications, charts and all the normal services needed for the safety and assistance of marine traffic along a shipping route are clearly the function of the government. There already exist in the eastern Arctic the main features of these kinds of services in some degree, and there are really no major technical difficulties in the way of increasing and improving these services as the growth of traffic makes it necessary.

One of the most serious deficiencies lies in hydrographic charts. Although a considerable amount of work has been done and the main routes are fairly well covered, there are still major gaps in the hydrographic survey of the eastern Arctic, and most of the new places to which ships are now penetrating in support of exploration activities are uncovered.

The work is being done as quickly as resources will allow, but it will be a long time before Arctic waters are as effectively charted as the more southerly waters. One of the main weaknesses in Arctic chart coverage up to now has been the inaccurate geographic positioning of many of the main islands and land masses. A programme has been started to reconstruct almost all the eastern Arctic charts, making use of the accurate shore lines and positions available from modern air survey methods. The Mercator projection will be used for all charts of this new series as far north as the latitude of the Parry Channel and the Polar Stereographic projection will be used for the Queen Elizabeth Islands. Soundings will be in meters.

Except for a few elementary beacons in particular locations, aids to navigation are virtually non-existent. Fortunately in most parts,the topography of the islands makes radar navigation relatively easy - or at least will do when the geographical inaccuracies mentioned above are removed - but nevertheless, there is need for the installation of some artificial aids to navigation in order to improve navigational accuracy. The extremely high cost of full scale installation of a sophisticated electronic navigational system is hardly warranted yet by the volume of traffic, but there are a number of options which are under consideration and this subject is being covered in more detail in another forum.

Communications difficulties because of Arctic atmospheric conditions are notorious and blackouts are fairly frequent. Within this handicap, the present marine network is adequate for commercial traffic but falls somewhat short for Coast Guard needs. Growth in Arctic activity and traffic will dictate a need for an overall improvement in this area.

An ice support organization generally similar to that of the Gulf in winter already exists: it provides for reconnaissance for the gathering of raw information of the ice situation, the analysis and digestion of this and the broadcast of existing and forecast conditions, ice operations offices for direct liaison with ships, and icebreaker support. In the last year

or two this has been moulded into an organizational pattern to suit the present state of traffic development and has the resources to support adequately, the scale and scope of present shipping activity. However, if present projections turn out to be accurate and the number of ships operating in the Arctic increases considerably, there may be a need for increased icebreaker capacity.

An extension of shipping into winter would introduce new demensions. The understanding of icebreaking theories and of the problems of ship operation in ice has taken large steps forward in the last half decade or so. Not even the newest of major Coast Guard icebreakers was designed in the light of this new knowledge, and none can be regarded as polar icebreakers for the kind of extended season operation that has only been seriously considered very recently. Furthermore, operation in the ten tenths ice conditions of an Arctic winter will require a far more sophisticated system of ice reconnaissance and reporting to allow the ship to find or to be directed to the easiest local conditions than is possible under the present system of broad area routing.

Terminal

There are in the Arctic no organized harbours with cargo handling facilities of the kind found in more travelled waters. Even Resolute and Frobisher which handle the largest tonnages lack harbour works, and cargo is handled over the beaches. With further expansion this situation may change in places, but it is difficult to see at this stage what form government participation should take.

In many of the sites of the Arctic, the only or the primary consignee of cargo and user of the port is a single mining company or exploration compny. In effect then, the harbour is a private one and the onlus is on the company concerned to provide what facilities they think are needed in exactly the same way as is done elsewhere. In multi-customer places, the onus will rather be on the Ministry to establish a harbour organization to co-ordinate the development of the complex, and even to provide government facilities.

Perhaps the major question is whether there should be one or more major ports acting as central distribution points. To some extent this situation already exists in the case of Resolute, to which a considerable volume of material of all kinds is shipped by sea in summer for distribution, mainly by air, to those locations which cannot be reached by sea. Originally established for the purpose of supporting the Joint Arctic Weather Stations' programme and the High Arctic defence installations, Resolute now carries out the same function for many other users.

Selected rather hastily and on the basis of the rather sketchy weather information then available, Resolute is not altogether the ideal site. There is something of an unfavourable micro-climate at the airport, and from the point of view of shipping, ice tends to concentrate in the Bay under certain conditions and the size of ship that can enter the Bay is restricted by a bar. This has not so far proved a serious handicap, but could be with more traffic and larger ships. There have therefore been suggestions from time to time that the bar should be removed and a break-water built to keep drifting ice out of the harbour. It has also been suggested that a more suitable port should be developed, and Radstock Bay, some 70 miles or so to the eastward of Resolute, seems to be the favourite. Indeed a year or so ago a private company was formed to develop Radstock Bay as a sea and air port and a distribution terminal, and land leases were granted. At present there does not seem to be any consensus on the essentiality of the Radstock Bay development, but if there is major growth in the Arctic, unquestionably something of this kind will be needed. Even though individual companies will tend to ship direct to locations close to their operations, this cannot always be done for all shipments, even by sea, and in the case of air shipments, it would hardly be practical for large aircraft flying from the Canadian heartland to call at every location where a small parcel of cargo was to be delivered, and furthermore such aircraft would require landing facilities impossible to provide at every location.

For the present, and for a few years to come, unless there is a phenomenal acceleration in growth, Resolute should be adequate, and for some purposes could be kept so more or less indefinitely. The crunch question therefore seems to be whether to start with the development of another site on the assumption that eventually Resolute is bound to become swamped, or whether to remain with Resolute until some more definite indication of the rate and pattern of growth in the High Arctic is evident or until the situation makes a move imperative.

There is of course also the question of whether a new terminal site should be developed as a private enterprise or whether it should be a government operation from the start. There are arguments on both sides, but undoubtedly in the case of an airport, control and administration and the provision of many of the facilities will have to be undertaken by the Federal Government, and to a lesser degree this would be so for the harbour. In addition some sort of co-ordination and control would be required for the warehouse area and townsite, though this need not of course necessarily be undertaken by the government.

Vehicle

The question of whether the government should provide the vehicles for Arctic marine resupply transportation is almost rhetorical. Are conditions so specialized or the circumstances so different that the private sector cannot or should not undertake this? This question has, we suggest, already been answered in the way in which Arctic transportation has evolved up to the present.

The combination of the realization by ship owners, ship operators and shippers as a result of experience in the Gulf over the past decade or so, that navigation in ice congested waters is perfectly practical given the right kind of ships and the kind of support organization provided by the Ministry, together with the appreciation that summer operations in the Arctic are not that different from the Gulf in winter, has created a tendency to move from the highly organized, centralized and controlled annual

one-time operation of the late 1950's towards a more general commercial shipping pattern. In general terms there is a tendency today for a shipper, whether government or non-government, who wants to send something to the Arctic to use the same methods as if he was sending it to Pondicherry or Patagonia. This is of course a considerable over simplification as there are such things involved as the use of different kinds of ships specialized for the area and the dependence on special support services for operation in ice. Nevertheless, the fact remains that the same evolutionary pattern that has taken place in the Gulf is manifest in the Arctic with familiarity breeding not contempt, but the realization that if treated with respect the Arctic is not so hostile and impenetrable after all.

If the shipping industry has already moved confidently and successfully into the field of Arctic marine transportation, and Canadian shipping companies can themselves provide the vessels that are wanted, what need is there for a government owned or operated eastern Arctic service? As our experience has demonstrated, this also applies to the government's own requirements.

There may be some special situations where the Government must provide its own carrier and perhaps such a situation might arise if it is found to be economic to adopt an intergrated ship/skycrane operation for the government component of resupply.

Another situation might arise if the volume of East Arctic resupply rose to a point that available shipping of a type able to comply with Arctic regulations was insufficient to complete the operation during the easy navigation season and it became necessary to extend operations into the ice season. This could lead to a requirement for so specialized a vessel that it could not be operated successfully by industry under regular market place conditions. But here again government operation is not the only solution.

Regulation

In the discharge of its responsibility for ensuring satisfactory standards of performance the Ministry has up to now not made regulations

for the type or performance of ships to operate in ice. It has been felt that provided vessels conform to the required standards of safety in general operation the question of what degree of strength and what special characteristics the ship should have for ice operation was a matter for the owner to decide in the light of the nature of his operation, risk of damage, operating benefits, additional costs, etc.

The situation has now been completely changed with growing concern over the risk of pollution in the Arctic leading to the passing of the Arctic Waters Pollution Prevention Act. Regulations made under this Act will stipulate the type of ship that may operate in what part of the Arctic at what time and what equipment must be carried. While it is unlikely that these regulations will have a major effect on ships already classed for ice operating within the geographical limits of the present resupply operation, but there will no doubt be some modification necessary and the operations of completely unstrengthened ships will certainly be affected.

Insurance

A major source of dissatisfaction relating to Arctic operations is the very high rate of permiums for the waiving of insurance warranties prohibiting operation in ice congested waters. At present these rates are regarded by ship operators as highly punitive and their effect on charter and freight costs is very great. Unless changed they could be a major factor in the rate of Arctic development.

While undoubtedly the risk of damage to unstrengthened ships operating in ice congested waters is considerable and a high rate of premiums can be expected for such vessels, it is claimed that the rates being charged to not altogether reflect the record of damage actually incurred from ice over the several years experience that we have had. What is criticized even more is that the gradations in the scale of premiums for different classes of ice strengthening do not adequately allow for the record of freedom from ice damage of ships built to the higher ice classes.

Over the years many representations have been made to underwriters for adjustments of the rates to conform more realistically to experience of ice navigation and although some changes have been made they are still a long way from meeting the views of operators on what is reasonable. The attitude of the underwriters may have been due in some degree to lack of first hand knowledge of actual conditions in ice congested waters. For some years the Ministry has maintained a sporadic contact with the warranties sub-committee of Lloyds and has provided them with records and reports to try to inform them of conditions, and as recently as this spring an official of the Ministry met members of the Arctic Sub-Committee in London to explain in detail the pattern of the summer operation, the characteristics and distribution of ice during this season and the organization maintained by the Department for supporting ships in ice. In addition the Ministry has suggested a visit by members of the sub-committee to observe at first hand the operations of ships in ice in our waters.

The role of the Ministry in this field has been confined to keeping the underwriters informed and the Ministry has taken no part in actual negotiation or discussion on rates. While there have been suggestions that the importance of development of the Arctic is such that the government should itself undertake the additional insurance of Canadian flag vessels for operation in ice or at least give some support, but hitherto it has always been flet that except in war the underwriting of vessels was not a proper function of government.

Other suggestions have been for the formation of some sort of club for the ships operators and owners engaged in trade in ice congested waters to take over the coverage of ice damage. Indeed this was explored by Gulf operators some years ago but was not found to be practical at the time.

Restriction of Arctic Trade

As a measure to improve the viability of trade into the Arctic and to offset the very much higher cost of operation and of construction of the types of vessels needed, it has been suggested that the Arctic trade should

be restricted to Canadian flag ships. While this would certainly be of benefit it would seem practical to consider this only for movement between the Arctic and a Canadian port. In principle it might not be easy to justify treating foreign trade into an Arctic port differently from any other Canadian port and to prohibit an operator in the Arctic from bringing in a cargo from overseas. Such an action could also carry with it the possibility of reciprocal sanctions. In the case of movement between Canadian ports the situation is of course entirely different and the whole question of cabotage, of which the Arctic trade is a part, is now being actively examined. In this connection a change was made in Ministry policy this year which will in the future restrict the charter of vessels for the government sealift to those of Canadian flag.

RE-SUPPLY: A REVIEW

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It is probably important to understand Panarctic's requirements, in order to fully consider the dependency thereby created on a reliable marine re-supply route. The drilling program undertaken by Panarctic has a very short fuse and any delay or miscalculation could prove to be costly in terms of land acquisition, with the possible resultant loss of valuable petroleum and natural gas reserves. Generally, any time a company in the oil industry becomes a farmee in thirty or more separate agreements, it has taken several years to put those agreements together and consequently the effective dates vary over a considerable period of time. This, of course, allows the exploratory program to spread over the same period of time as well and is usually tied very closely to the farmees long term budget requirements. In Panarctic's case many of the farmin agreements carry a common effective date and although the earning requirements are spread over a period of years, this spread is common to virtually all agreements. The obvious problem is that Panarctic is required to do a vast amount of exploration and drilling within time limits set by these agreements. The earning requirements of one agreement cannot be looked after before moving on to the earning requirements of the second agreement but rather in many instances, the earning requirements must be looked after simultaneously. Upon analysis of a "standard" earning agreement, it becomes apparent that the farmee is required to drill a set number of wells, to earn a specified interest in a portion or all of the farmed out land. The farmee may have an option to earn additional lands or larger interest in the lands already earned, by drilling additional wells. The agreements in which Panarctic is involved are by no means this simple. Many of the Panarctic agreements by simply completing a certain dollar expenditure on exploration in the Arctic Islands, enables Panarctic to earn a specified interest. The company then has the right to elect to exercise its first option. When this is done, the amount of money to be expended in exploratory work increases and in some instances a definitive drilling obligation comes into effect.

By exercising option number one, of course, Panarctic increases the percentage income earned in the farmed out lands. A second option can be exercised and once Panarctic decides to do this the expenditure increases

and in some cases, but not all, additional drilling is required in order to increase again the percentage the company can earn. A final option can be exercised and upon electing to exercise, Panarctic commits to spend additional sums and again in some instances takes on further drilling obligations.

As a result of these options, the interest to be earned by Panarctic in the permits, subject to any one specific agreement, can vary from as much as 16 to 95%, depending on the individual agreement. A planned drilling program can become very complex when one has to consider the various options under all of the various agreements. The exercise of these options is further complicated by the right that Panarctic has to ask for one year extension periods. Depending on when this right is exercised, the critical dates change and consequently under every agreement Panarctic has to consider as many as five different sets of dates by which time it has to complete the earning requirements. In order to meet these deadlines, it has been necessary to schedule a drilling to accommodate not only the agreements but the environment.

It has been found to be much more costly to move drilling equipment in the dark and often hazardous, if not impossible, to move during the short summer period. With these factors (and bearing in mind that there is a stand-by charge on each rig, even while it may not be drilling), stockpiling and inventory build up must be advanced in order to accommodate rig moves in the spring and fall, which are calculated to satisfy the obligation commitments. It takes little imagination to estimate the dangers to a program so critically planned should any one of a series of possible delays occur.

While the drilling program is being pursued, data from each of the wells is being analyzed, as is that obtained from the geological field parties and seismic programs and it would be a most unusual exploration area if these data did not provide evidence suggesting and requiring that further changes be made in the program, in order to make the best use of the information and material thus obtained.

Logistical studies, planning and the implementation thereof account for approximately one-third of the total time and expenditure of the company. The original basic exploration program required Panarctic to drill or commence between nineteen and thirty wells, depending on options prior to the end of 1972. There are minor exceptions brought about primarily by the various combinations of options which can be elected but the 1972 is critical. Had this programme been undertaken on the basis of a concession such as was once granted in the Middle East; or similar to the original legislation during the early stages of exploration in Australia; or subject to the same legislative climate as existed in Alberta in the early 1950's; or had Panarctic been the first owner of all of the permits, then a more methodical and less expensive method of attack would have been devised. In anticipation of this obligatory drilling program, it became necessary to capsulize geological and seismic surveys, which would normally have occupied the first three to five years of a normal program, into two short summer seasons.

There was no time to consider the use of the Eastern Seaboard in 1968, except to stockpile for future wells. All of the early camps and material essential for field operations, as well as the first two drilling rigs, were flown to the sites from Yellowknife. In fact, due to rig availability, our other commitments, and the difficulties which one would expect in attempting to navigate both Jones and Eureka Sound during the month of January, Rig 4 will also be flown north from Yellowknife this winter.

Air transportation is the first preference of the company. It is fast, it is efficient and it is reliable. It is also more costly, so except in the case of emergency or in a situation which is absolutely intolerable as far as the programming is concerned, heavy and bulky material as well as fuel make a sealift mandatory.

During preliminary studies of sea transportation systems, it was assumed that there were four possible routes. The most logical for obvious reasons originated from the Eastern Seaboard. Some consideration was given to the possibility,

due to its proximity, of shipping out of Vancouver and along the north coast of Alaska but the risks were easily definable and the savings, if any, could not be equated against the odds of reaching the destination. A third route, also dominated by the time factor, was the use of the MacKenzie River transportation system to Inuvik and thence through Prince of Wales Strait to Melville Island. It was never necessary to consider the problems to be encountered in the northern end of Prince of Wales Strait, since the short shipping season could have delayed the arrival of our supplies by many months and, in fact, in retrospect, would have undoubtedly required an airlift from Inuvik. The fourth possible route was from Churchill on Hudson Bay. Here again the arithmetic of economics and the bathymetric horrors of Fury and Hecla Strait, ignoring if one can the ice in Foxe Basin, brought about an early demise to this proposal.

The risks, as evidenced by two material consuming wild wells and the barge venture, to the company must be related to that area of activity which the company understands and presumably knows best, that is to say the exploration for hydrocarbons. Although this philosophy had been predominate from inception, it was corroborated by the rather more than cursory study made of available routes, and has been substantiated by what is felt to be a series of successful marine voyages to both Melville Island and Ellesmere Island, so that the safe way has proved to be the best way.

Early in 1968 plans were made to transport dry drilling material, pipe and fuel to Melville Island, which was to be the location of the first well in the program. The company had become interested in the Alexbow Hammerhead Icebreaking device by this time, so that the combination of an ingoing sealift and outgoing trials of the device became possible. The Alexbow trials, however, and the subsequent installation of an Alexbow on the "L. A. LEARMONTH", were a secondary consideration in the decision to use the barges. The "SCOTTY GALL" which transported 275,000 gallons of valuable fuel to Melville

Island, was built to provide fuel storage and as such has served that purpose adequately. The "L. A. LEARMONTH" was also a fuel barge although used for dry cargo on this and a second trip.

The barge configuration was determined as the best possible for use during unloading operations, expecially from the "L. A. LEARMONTH" which was unloaded across the "SCOTTY GALL". In an area where harbour facilities are limited or in many instances non-existent and manual labour is the only source of power, even crude facilities such as these barges offered, were an improvement over the possible alternatives. The subsequent use of the "SCOTTY GALL" in 1969, as a base across which the contents of the "THORA DAN" were unloaded, resulted in considerable savings in both manpower and material. The 1968 sealift stockpiled 275,000 gallons of fuel and 2,000 tons of drilling material at Rea Point on Melville Island, which was then transported to Drake Point, Sandy Point and Marie Bay during the drilling of those initial wells. In 1969, the successful sealift to Fluker Point, south of Eureka on Ellesmere Island, saw some 2,000 tons of drilling material deposited on the beach and 4,500 tons of drilling supplies and equipment deposited on the beach at Rea Point on Melville Island. It had been anticipated that a further 275,000 gallons of fuel, to be pumped into the "SCOTTY GALL", would be delivered to Rea Point and at the same time our inventory would be increased by the 2,000 tons of expendables carried by the "L. A. LEARMONTH". While the fact of the loss of these barges should not be minimized, the precaution of taking additional material on the "THORA DAN" and of stockpiling fuel at Resolute lessened the effect on the drilling and exploratory program. In 1970 under some awkward circumstances, the company unloaded a further 2,000 tons of drilling equipment, camp and pipe at Fluker Point and in addition has now stockpiled over one million gallons of fuel at Fluker Point and Eureka. In three years, therefore, 10,500 tons of material and supplies and 1,475,000 gallons of most valuable fuel has been transported to the high Arctic and deposited at locations of the company's choice.

Although experience has shown that heavy bulky material can be transported to the Arctic cheaper by freighter than by air, many of the items have to be handled as often as eleven times, from point of origin to

final destination, when using sea transportation; greatly adding to the already heavy transportation costs. During 1969, 10,000 tons were delivered directly to the various drilling and base camp locations by air. Airlift required 75% less handling than sealift. The airlift from southern Canada was accomplished by the use of chartered Fairchild F-27's, Douglas DC-4's and DC-6's and by Hercules L-120. A Lockheed Electra freighter, which went into service for Panarctic early in 1970, has further streamlined the freight and passenger hauls and is expected to allow greater flexibility with increased savings and transportation costs during the coming months. Inter island positioning of material stockpiled by sealift was done largely by Hercules and in the summer months by Bristol Freighters. All phases of the operation, that is, support, personnel transportation, geophysical surveys, material transfer and rig moves required in excess of 12,000 hours of flying during 1969.

The trip to Ellesmere Island and Fluker Point, by way of Eureka Sound in 1969, by the "CHESLEY A. CROSBIE", was a first in the annals of Canadian commercial shipping. Unfortunately, this significant feat was overshadowed by the efforts of the "MANHATTAN" to navigate McClure Strait. The effort in Eureka Sound was duplicated in 1970 with the "CHESLEY A. CROSBIE" making a return voyage, accompanied by the "EDOUARD SIMARD", a tanker, thereby ensuring that the appetites of the company's iron will be satiated during the early part of the program on Ellesmere Island. These voyages should not be treated lightly, as those who are familiar with the area will acknowledge, and would not have been successful had it not been for the early experience of Dome Petroleum personnel at Winter Harbour and the advice and knowledge provided by the shipping companies with whom Panarctic has been associated in these ventures. Undoubtedly, pioneering attempts will be made by Panarctic throughout the Islands into areas not yet penetrated by commercial vessels, thereby contributing to the knowledge presently existing of the peculiarities of marine travel, not only in the Eureka area but also west and north of Lancaster Sound.

It is anticipated that with the research and development presently underway, with respect to the Alexbow Hammerhead icebreaking device, forays into the heretofore most difficult areas of the Archipelago will have a greater chance of achieving success. It should be pointed out that the loss of the "LEARMONTH" and the "JOHNNY NORBERG" despite any irresponsible statements which may have been made, was in no way connected with the Alexbow Hammerhead. Some research is about to get underway in Canada with the Alexbow design. It is expected that a third generation of the device will be launched in Scandinavian waters early in 1971 and at the same time, far reaching negotiations are currently underway for more research and widespread application from the Gulf of Bothnia westward. It would be of considerable satisfaction to Panarctic if the technological advances thus expected were to coincide with the necessity of transporting either oil or natural gas from the Islands to the market place.

The matter of costs in any lift of material or personnel to the Arctic, whether it be from Edmonton, Calgary, Yellowknife or Montreal by either air or sea, have to be viewed with a considerable amount of caution and in infinite detail. The use by Panarctic of several different types of aircraft and by combining the airlift with road transportation from Edmonton to Yellowknife, raises questions in a number of different combinations. Comparable figures would therefore have to exclude the transportation of personnel and those bulky items such as buildings which distort the cost per pound of air transportation and present an incorrect perspective. Nevertheless, the entry of the company's Electra into the transportation field has given us greater control over costs to and from the various locations in the Arctic and has had an interesting effect on competitive rates. On average we are currently showing a cost of between 35 and 40¢ a pound for material transported to the Islands, whereas about a year ago that same figure would have been 50¢. Marine costs are in the 15 to 18¢ per pound range, which at first glance would lead one to believe that there was a savings of between 60 and 70% by using the shipping facilities available to us. There are, however, many intangibles which cannot be reckoned, but it is safe to assume that the difference is closer to a 20 to 25% range which difference, of course, is still sufficiently attractive to justify the use of the sea route.

In order to arrive at the sealift costs packaging, loading and unloading as well as direct transportation figures were used. Not included were the costs of rail transportation from the point of origin of the material to the dockside, nor was the cost of damaged goods taken into consideration. Before any misunderstanding takes place, it should be pointed out that Panarctic's loss history, aside from the barges, has been substantially lower than provided for using any of the normal known parameters. Nevertheless, this item can be a significant factor and programme difficulties could be encountered involving higher costs by virtue of replacement by air, due to the time limitations. The company, with the co-operation of its associates in Montreal, has been conducting some experiments with respect to packaging and unloading techniques. At this time, it is safe to say, that more progress is being made in packaging than with unloading techniques and the use by the Department of Transport of a Sikorsky Sky Crane at Resolute may be the breakthrough required to overcome the challenge of ice rafted beaches.

Insurance rates, as applied to vessels, fall just short of being prohibitive. Panarctic has been conducting its own program of education with the underwriters and brokers directly involved but finds that the knowledge of actual operating conditions in the Arctic so lacking in depth and over romanticized that no early results are anticipated. Certainly the loss of the company's barges did nothing to generate confidence in the minds of the underwriters. The stipulations with respect to the time that vessels must be southbound bear no relationship to the vessels now employed in this service, nor do they appear to take into account the vastly increased knowledge of ice conditions and the surveillance of these conditions which is presently available. Although the company's record has been eminently successful with self powered vehicles, the barge episode would undoubtedly detract from any criticism which could be leveled in the future, should improperly strengthened vessels be utilized north of 72^{o}. Hopefully the new pollution regulations will take this factor into account. The argument to underwriters should be based on the experience of knowledgeable persons

for the conduct of the operations and in this regard it could reasonably be expected that the officers commanding the Canadian Coastguard icebreakers, who have provided such excellent service, would be in the forefront. It is to the advantage of all concerned to ensure both by commission and censure that honest, accurate and knowledgeable information is provided for the insurance industry, so that the necessary relief from the presently unrealistic rates can be achieved as soon as possible.

There is a further danger to Canadian shipping and Canadian industry in general and it emanates from the regulations requiring the use of Canadian ships if duty is to be avoided. The pipe and other drilling supplies required are all available elsewhere in the world. Ocean going rates can be negotiated most favourably with rail transportation rates to the Eastern Seaboard, so that with ice strengthened vessels available, it is simply a matter of negotiating the best rate with either a Canadian or a foreign flag vessel from 54° north. The absolute shortage of Canadian ice strengthened vessels, placed the shipper at the mercy of the shipowner, and either we must have more ice strengthened vessels available, in order that competitive bidding may be achieved, or the oil industry may be forced to obtain its supplies and its vessels abroad. Due to its Canadian content a decision made by Panarctic in this regard is not lightly taken but the lack of vessels of an appropriate size and ice strengthening will continue to plague those planning marine re-supply.

Great things, some of them hard to visualize are currently predicted for the Canadian Arctic in the future. In order for these developments to take place, and it appears that they contemplate domestic occupation of the area, vast improvement in navigational knowledge and communication will be a prerequisite. In the meantime, and assuming these developments, a start could be made in both the fields of communication and bathymetry. Even with the assistance of the "SCOTTY GALL", the "THORA DAN" could not possibly have been unloaded at Rea Point in 1969 had not it been for the work performed by the Canadian Hydrographic Service, at the small indentation on the shore line referred to as a harbour. A correlated program based on data which could be assembled from the various oil companies and research

projects now underway in the Arctic, could provide the much needed information leading to the location of probable unloading areas. That the co-operation of the oil companies could be obtained is a foregone conclusion, if for no other reason than their own future requirements. Similarly a program, even if long range, of bathymetric studies conducted not only in the conventional manner but also using the data already compiled by the oil operators, would in time provide the essential charts which, even if the long term dreams do not come true, could be well and truly utilized commercially in the immediate future. Naturally, it could be assumed that with the increased communication system, greater strides will be made in weather forecasting and ice condition prediction, so that the improbable may turn out to be the probable and eventually the likely in terms of arriving successfully by ship at an inter island destination.

Indeed the necessity for a vastly improved communication network, better forecasting and adequate charts will be needed, if the sea lanes are going to be able to compete effectively with large jet aircraft freighters. The only limitation to aircraft of this kind in the Arctic, at the present, is the current lack of knowledge as to how best to stabilize a sand runway. Research in this field has just started and with the rates which could be obtained it must be continued, even if it only brings about a reduction in sealift costs.

In considering the future of an eastern re-supply route and in fact the future of shipping in the Arctic, care should be taken not to become over optimistic as a result of the romance surrounding that part of the world or those industries which are attempting to relieve the area of its valuable mineral deposits.

A little arithmetic, partly factual and partly hypothetical, will present some conclusions as to the rate of acceleration which will be required to support just the search for petroleum and natural gas.

Assume that Panarctic's twenty well obligation programme is now about to commence. If it takes approximately six months including rig move to drill a 12,000 to 15,000 foot test, then three drilling rigs could accomplish this feat in three and one third years.

Obviously this is a pure case, due to the options, but if the time were to be doubled to six and two thirds years then the supply requirements would obviously be stretched out over a similar period.

A rig and the necessary supplies to drill the 12,000 to 15,000 feet will require a lift of approximately 3,500 tons. Once the rig is in place, it can only be transported from site to site by air and since the rig weight comprises some 800 to 900 tons of the total original lift required, the remaining seventeen wells, assuming three rigs are utilized, will require approximately 2,700 tons per location. About one third or 900 tons of the 2,700 tons referred to above, is comprised of bulk fuel which can be moved to a terminal by tanker and transported either by air or overland from that base. The fuel figure, however, is an over complication. The original move in this hypothetical case involved three rigs totalling, with consumables, 3,500 tons for a total of 10,500 tons in order to get the programme underway. (The resemblance of this figure to the material which has been transported by sea to date is purely coincidental). In addition, there would be a requirement for a further 2,700 tons each for the seventeen remaining wells approximating a total lift of 46,000 tons.

A movement of this nature could be accomplished by virtue of nine trips in a vessel, capable of lifting 5,000 tons per trip. Such a vessel is, of course, not available in Canada in an ice strengthened state, so that we could conceivably be looking at 23 trips in vessels of a 2,000 ton capacity.

These trips, of course, would extend beyond Resolute both to the west and to the north and it becomes immediately apparent, that there would be no way to accomplish such a sealift with the bottoms available, in either three and one third or six and two thirds years given the present shipping season in the Arctic, but three 5,000 ton vessels could do it in three years. Seven 2,000 ton vessels could probably do it in three years with the added advantage of being, in each instance, more capable of getting closer to the drilling site and thereby decreasing the amount of flying time in transporting from the beach to the location.

By way of reference in relation to future requirements, there are currently under lease in the Province of British Columbia, which has been under active exploration for in excess of fifteen years, at the present time 42 million acres and the total dollar expenditure to date has amounted to 580 million. In Alberta, where exploration has been underway since prior to the first world war, but accelerated from the 1950's onward, there are currently held, under lease, some 85 million acres but the expenditure to date in this case equals 3.3 billion dollars. Panarctic has under permit, at this time, in excess of 50 million acres and has spent approximately 38 million dollars.

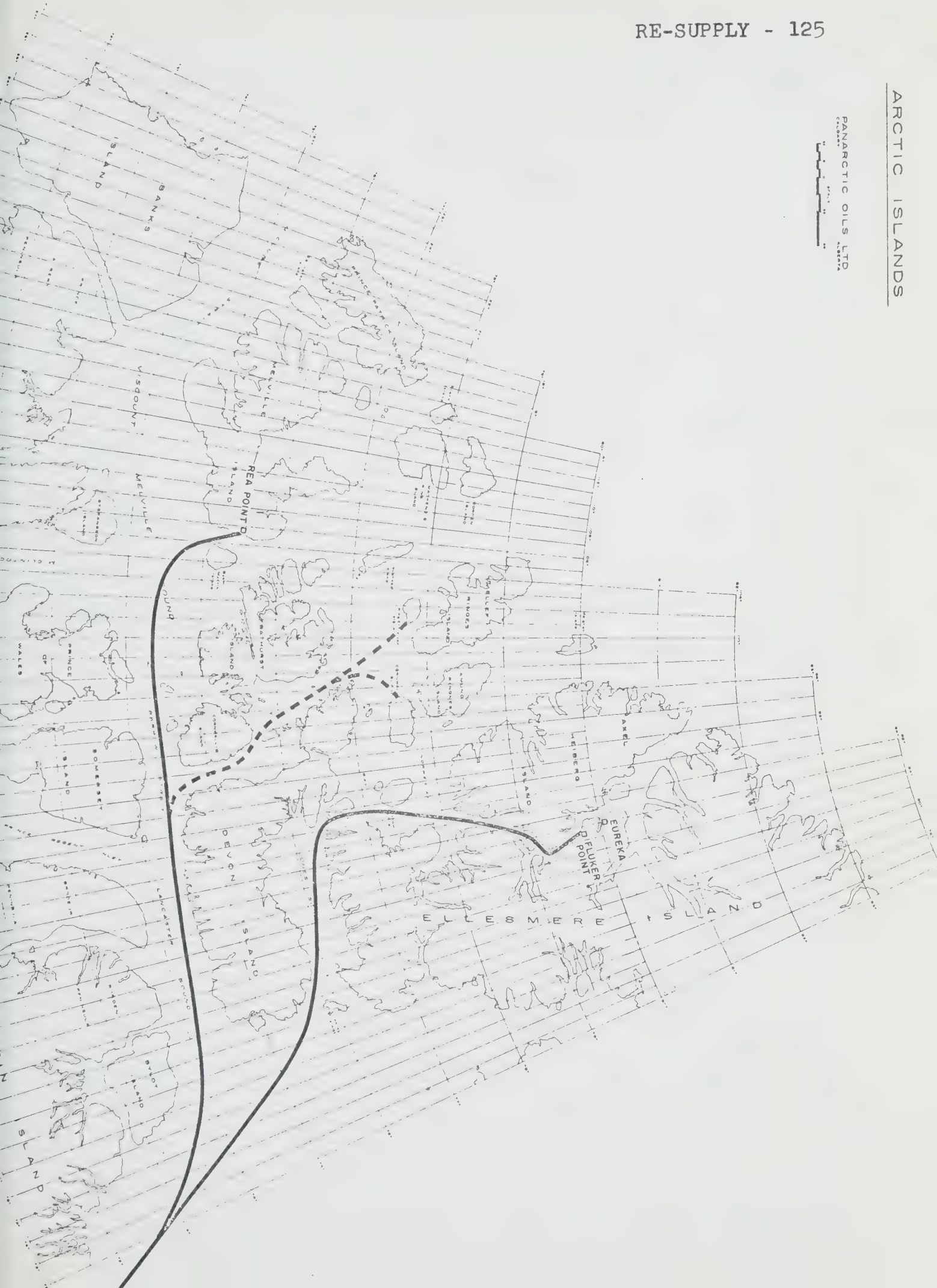
It is no secret that the Arctic is a hostile environment and that it is foolish to contemplate completing a programme of this magnitude in either three and one third or six and two thirds years. So the matter of re-supply can be looked at more comfortably when considering the shipping which is available. Panarctic has, however, by virtue of having farmed out some of its obligations, achieved a point in its primary exploration programme, whereby with the help of the farmees the obligatory wells should be drilled no later than the end of 1973. A continuing programme both by Panarctic and others, who have land holdings in the area, is contemplated so the tonnage and number of vessel figures must be used in their proper context. Namely that of an example.

The conclusion is that the environment controls the rate of progress in the Arctic and that short of brief flurries during those periods when newly discovered fields are being developed, the vessels currently available in Canada and abroad are just adequate.

Even with the introduction of other operators, both independent and farmees, and the transportation of vast quantities of material to the Arctic by air, it is now considered to be possible to complete the programme in less than six years. It is reasonable to assume that a rate of exploration roughly comparable to what may be expected in 1971 will continue, short of further discoveries, for at least five to ten years.

ARCTIC ISLANDS

PANARCTIC OILS LTD



EASTERN ARCTIC TRANSPORTATION BY SEA IN THE 1970'S

BY - B. N. MALOTT

Before looking at the current picture and at the prospects for the immediate future, I think we should have a brief review of the past. Prior to 1956 the movement of supplies into the Eastern Arctic was relatively small and was taken care of by the few Canadian Government ice breakers which we had at that time, augmented by one or two small time-charted vessels.

The volume of cargo increased substantially after 1956 with the building of the DEW LINE, MID-CANADA LINE, and other Defence Systems. As these sites were established, the Department of Northern Affairs and Nat ural Resources, now known as the Department of Indian Affairs and Northern Development, became very active. The volume of their annual traffic has continued to rise as the volume of Defence traffic has fallen off with the growing obsolescence of these particular systems.

All in all, the volume of traffic in this short period of fifteen years has risen from about 5,000 tons in 1955 to almost 100,000 tons in 1956, and it has remained fairly constant at the latter figure for almost the entire period.

During these years there has always been a small quantity of supplies moving forward for various mining developments to assist in exploratory work, and this would range from, say, 2,000 to 10,000 tons per annum. The only mine to be brought into production during this period was the North Rankin Nickel Mine at Rankin Inlet on the West coast of Hudson Bay. We had the distinction of transporting their Concentrator Mill in the late 50's and

also carried their concentrates for two years. The first load of concentrates, about 1800 tons, was brought to Montreal, but thereafter it was shipped the short distance from Rankin Inlet to Churchill and thence railed to the Sherritt-Gordon Refinery at God's Lake. This property was of a marginal nature and as soon as the main ore body was worked out the mine was forced to shut down in the early 1960's.

There are two other major mining properties in the Ungava Peninsula that have been explored over the last few years and are in the process of development. The property at Asbestos Hill owned by the Asbestos Corporation, after several stops and starts, now appears destined to go ahead and they hope that by the end of July 1972, their plant, storage and loading facilities will be ready for operation. Their target is an annual production of 300,000 tons, which will be shipped from Deception Bay to Germany in 50,000 ton vessels during the period from mid-July to mid-October each year.

The other property is high grade nickel ore owned by Falconbridge Nickel Mines Ltd. A great deal of exploratory and development work is being carried out, but to date no definite decision has been taken as to when the mine may go into production. If and when this takes place the ore and concentrates will likely be shipped from Douglas Harbour which is not too far distant from Deception Bay.

Other rich bodies of iron ore and base metals have been discovered in the Northern regions of Baffin Island. Here again a great deal of time and money has been spent in developing and proving these properties, but no decision has been taken to bring them into production.

It is interesting to note that only two mining properties that have been in production or will go into production in the next two years are in the lower Arctic, as compared to the High Arctic where costs are much greater. The main cost item is, of course, Marine Insurance and the additional premiums charged for entering Northern Waters. These additional premiums are based on the G.R.T. of the vessel and its insured value. The total additional premium on a 50,000 ton DWT non-icestrengthened vessel entering Milne Inlet would be approx. $500,000.00 for one voyage. If the vessel was icestrengthened to Lloyds standard Class I, the additional premium would be 50% or $250,000.00. If the same type of vessel were to enter Deception Bay the additional premium for a non-icestrengthened vessel would be approsimately $150,000.00. If it had the highest ice class of Lloyds it would be reduced to about $75,000.00 or approximately $1.50 per ton of Cargo carried. The Arctic is divided into different sectors with different scale rates applying for each sector, depending on the severity of conditions, etc. There are also specific dates laid down for each sector during which one can trade into these areas. If a vessel enters earlier or departs later than the dates laid down there are again heavier additional premiums which are assessed at the whim of the underwriter.

From the foregoing examples it can be readily seen that the cost of additional insurance alone in the North Baffin Island region could range from $5.00 to $10.00 per ton of ore, depending on the Ice Class of the vessel, whereas in Hudson Straits these costs would range from $1.50 to $3.00 per ton. Again, in the Far North the period of trading is limited to about six weeks, whereas the Deception Bay period extends to about three months.

During the last 15 years our vessels have traded to all sectors of the Eastern Arctic, but not west of Resolute Bay in the Lancaster Sound Region. I have, as a result, had a good opportunity to study the conditions and risks involved, and it is my considered opinion that the rates are far too high, and that in all areas the trading limits could be extended by two weeks. According to my observations, the casualties to all vessels engaged in Northern Supply operations have been relatively light over the years, and I attribute this to the prudent type of operation and the excellent, experienced officers employed on the vessels.

It is unfortunate that the insurance market for our Arctic regions is relatively small due to the small trade in the past, and also that it is centered in London. I have been informed recently that the rates may increase next season, whereas we in the ship-owning and operating field believe that they should be reduced. I think it might be advisable for the Canadian Government to sponsor a trip next summer for the leading U. K. underwriters to the various sectors of the Arctic, so that they could gain first-hand knowledge of actual conditions, air reconnaissance, ice-breaker support, etc. I believe that it is only in this way that we can hope to secure improved rates and conditions.

If it is impossible to secure substantial reductions in the additional premiums then the shippers or the consignees, depending on the terms of sale, may have to decide to acquire their own vessels to carry the cargo and operate on a self-insured or T.L.O. (Total Loss Only) basis.

During the last three years we have entered into a new phase in the Arctic Archipelago dealing with oil explorations. So far this has involved the carrying of a fair volume of cargo by vessel, but only around the perimeter of the area due to heavy ice conditions in the Western, Central and Northern

parts of the Archipelago. Several test wells had been put down a few years earlier, but it is only in the past three years that an all-out drilling program was started by Pan Arctic and other major oil companies. What will happen in this region is not yet known. I would imagine that the exploratory program will carry on for another three years with from 10,000 to 20,000 tons of supplies being carried in each year. However, if there is a major oil strike there is no doubt that the increase in activity would be tremendous. Of course, the supply of material to this area must be a combination of Sea and Air, as it is very difficult for a vessel to penetrate beyond the southern and eastern perimeter of the area. Aircraft will always be used extensively in carrying rigs to inaccessible spots within the archipelago.

It is very difficult to plan for the future because one does not know what the requirements will be....which projects will be brought to fruition ....the location of the projects....the quantities of supplies that will be required on the actual sites....the quantities of ore, concentrates or crude oil to be shipped outward, and their destinations.

It would appear logical that two types of vessels will have to be used in the Arctic in the future if there is any major commercial development. Regular type supply vessels to carry equipment, supplies and refined petroleum products into the various sites, as well as larger tankers, bulk carriers, and/or OBO's (Ore, Bulker, Oil) to carry crude oil, ore or concentrates outward. I have already mentioned that Asbestos Corporation plan to use 50,000 ton bulk carriers or OBO's to carry their production to Germany, but in all likelihood they will receive their supplies from Eastern Canada in smaller, regular supply vessels. The larger vessels arriving to pick up cargo will want to secure the quickest possible despatch, whether it be oil or ore, and

they will not want to waste time in discharging general cargo, equipment, or refined oil products. The bulkers would not normally be equipped to handle general cargo, and the loading installations might not be designed to receive general cargo. At Deception Bay for example, the vessel will berth at Dolphins and the asbestos rock will be loaded by two conveyor belts. By the same token a vessel loading crude oil in the Arctic would not want to take time to clean tanks etc., before carrying refined products into the region. Again, the crude loading depot might be far removed from the installations where the refined products are stored for distribution. However, it is conceivable that OBO's could be used where large quantities of heating oil or diesel fuel will be consumed by the shore installations.

If our Arctic region is going to develop we must endeavour to have the best and most economical transportation possible, and at this point I intend to deal solely with supply vessels. Due to our relatively short Arctic season, 3 to 4 months at the most, all supply vessels will have to be designed for a dual role - Arctic work as well as ordinary commercial deep-sea trading.

We will require both dry-cargo vessels and tankers. Due to the exceedingly high cost of building new vessels and continually increasing operating costs, one must decide on a size which will be not only the most economical but also the most feasible to operate in both Arctic and regular trading. Taking into consideration all factors, including draft restrictions in certain places, it is my view that a 15,000 ton DWT vessel with a cubic bale capacity of about 600,000 feet would be most useful. The average stowage of cargo moving into the Arctic is about 100 cubic ft. per ton, hence such a vessel would be able to carry about 6,000 tons. The ideal tanker for the trade would range from

16,000 to 18,000 tons DWT, and be capable of carrying about 4,000,000 to 4,500,000 gals. All these vessels should be self-sustaining as far as possible, and should have the following characteristics:

TANKERS.

1) Vessel should be ice-strengthened to the Class laid down by the Government for the particular area or areas which it may be called upon to serve.
2) It should be capable of carrying at least eight different products at the same time without the risk of contamination. This would involve special pumping and piping facilities.
3) It should have relatively low draft in relation to deadweight in order to enter certain bays and other points of discharge.
4) A minimum speed of 15 knots would be required in order to enable the vessel to make two trips per season, and also to compete in the outside clean trades.
5) It should carry special type of floating hose sufficient to reach shore installations where such equipment is not provided.

DRY-CARGO VESSELS:

1) Vessel should be ice-strengthened to the Class laid down by the Government for the particular area or areas which it may be called upon to serve.
2) Its Engines and Bridge should be located aft, which will give wide open deck space forward for the loading of deck cargoes and in case of need make it possible for helicopter discharge. Having engines aft eliminates the tunnel shaft, leaving flat tank tops for stowage of cargo.

3) Vessel must be equipped with large hatches capable of handling containers. Cargo may not necessarily be carried to the Arctic in containers, but we must bear in mind her regular commercial trade in the off-season.

4) Certain holds of the vessel should be single deck and equipped for handling containers or unitized cargo.

5) Holds in the balance of the vessel should have one or more tween decks for break bulk or unitized cargo, and should be equipped with elevators to bring cargo up to the top tween deck for ease in helicopter discharge. This section of the vessel should be equipped also with side ports for fast loading and discharge of unitized cargo in the regular commercial trades.

6) Vessel should have at least six large hatches and holds which will permit better segregation of cargo by discharge ports.

7) Additional accommodation and sufficient galley facilities should be provided for the small number of stevedoring personnel, helicopter crews and supervisors which will be required for discharge operations over and above the crew.

8) One heavy-lift boom (cap. 50 tons) should be provided for handling landing-barges, heavy equipment (cargo), and any heavy stevedoring equipment which may be required ashore. From past experience it is felt that a 50 ton lift should be available. It is necessary also that the vessel carry one or more barges capable of lifting heavy equipment and outsize pieces of cargo (such as mobile homes) which are heavier than

8; con. the lifting capacity of the helicopter. It must be remembered that the safe working load of the Sikorsky Sky-crane is about 8 short tons.

9) A certain amount of Reefer and Chill Space for cargo should be provided.

10) A minimum speed of 16/18 knots should be possible in order that such a sophisticated vessel may be able to compete in regular commercial trade.

11) Draft will not be a problem as the vessel will have less than half her DWT on board during during Arctic trips due to the high stowage factor of cargo (average 100 feet per ton).

12) Special tankage must be provided for helicopter fuel, as well as pumping facilities.

13) Vessel will have to be equipped also with special slings and platforms for carrying pallets used in helicopter discharge.

14) It will be noted that items 2, 12, and 13 make reference to helicopter discharge. We are all awaiting the results of the studies that the Government has been making over the past two years in this regard. With the development of helicopters and their lifting capacities, it seems certain that this will be the most economical type of discharge in the future, and therefor I feel that this must be kept in mind in all future designs of vessels for the Arctic.

The two types of vessels described above would be ideal for Arctic trading but they are very costly to build, and one would require a long term contract at rates which would assist in the amortization of the vessel over, say, a five or preferably a ten year period. As mentioned earlier, a great deal of our Arctic development is still in the exploratory stages, and no company or group of companies would be willing at this point in time to consider entering into a contract with a ship owner for an extended period of time. Hence it would appear logical that the Canadian Government which has a large number of ports to service should enter into such contracts with ship owners. It may well be that in the years to come it will be possible to arrange such contracts with commercial companies, but this is certainly not true in the foreseeable future.

The Canadian Government also will have to clarify its policy as to the Registration of vessels which will be allowed to trade into the Arctic. During the Spring of 1970 the Government abruptly changed its policy and stated that it would charter only Canadian Flag vessels to carry its cargoes to the Arctic during 1970. It was stated at the time that this was done to enhance Canada's claim to sovereignty over the Arctic Islands and the Northwest Passage. However, British Flag and Built vessels were allowed to carry commercial cargo from Eastern Canada to Arctic sites. Foreign Flag vessels were allowed to carry cargo from Foreign ports to Arctic sites also.

I feel that it is only fair that a common policy should be adopted with respect to our cabotage laws, and that only Canadian Flag vessels should be allowed to operate between two Canadian points. Perhaps this will be an answer to those groups who are clamouring for a small nucleus of a Deep-Sea Canadian

Merchant Marine. However, one must be fair and point out that it will cost a Canadian operator in excess of $100,000.00 to run a Canadian Flag vessel as opposed to a British Flag vessel, and he will have to be compensated in some manner if he is going to compete in Foreign trade during the balance of the season. It would appear to me that this can only be done through Government subsidy to the amount indicated. If our Canadian transportation costs become too high, then the companies engaged in exploratory work, or on a permanent basis in the future, will look outside Canada for their supplies, which will be to the detriment of our Canadian industries. This was done in part by Cardwell last season in establishing their depot of supplies at Resolute Bay.

Mr. Leonard (Red) McLaughlin, President of the S.I.U. of Canada, in a recent address before the Society of Naval Architects and Marine Engineers, suggested that the Canadian Government make it compulsory that all or at least a part of our Natural Resources be exported in Canadian Flag vessels, and in this way develop a Canadian Deep-Sea Fleet. However, this is a complete reversal of a policy established in 1948 and which has worked fairly well since that time. Such a policy certainly would be to the detriment of our development of the Arctic, unless the entire program of ship-building in Canada as well as the higher operating costs would be subsidized by the Government. I do not feel that the country should assume such a burden at this time, which would serve only to assist the ship-building interests and the S.I.U. (if they were in a position to supply adequate crews). As far as the ship-operating industry is concerned, there are many companies employing British and Foreign vessels on a successful basis and in so doing contributing to the Canadian balance of payments.

I believe that it would not be prudent for Canada to restrict the movement of cargo to and from Foreign ports to the Eastern Canadian Arctic, but we can legislate as to the type of vessel and the degree of ice-strengthening required in the various sectors which is necessary from the standpoint of pollution. What would happen to our export of grain out of Churchill if its movement were restricted to Canadian Flag vessels? It would be non-existent without a subsidy.

In the future I expect that there will be two or perhaps three sites in the Arctic north of Hudson Straits which will be used as distribution points for cargo which will be carried eventually by Air to Destination. In the Far North one of these points will be at Resolute Bay or Radstock Bay, and perhaps some comsideration should be given to developing facilities at one or other of these points, in the event that a large oil deposit is found. I am thinking of a permanent causeway which would enable conventional ships to discharge alongside. Farther south at Frobisher Bay consideration should be given to repairing and improving the existing causeway, or perhaps building an entirely new installation just to the east of the main landing beach.

Gentlemen, as you see this phase of transportation to the Arctic is a very complex one. I have dealt only briefly with the technical and commercial aspects, and have not touched on the other problems of ice, high winds and extreme temperatures that may be encountered late in the season.

I have always held a strong belief that there is a great future in the Arctic, and feel that we are on the brink of tremendous commercial expansion in the area. We in the ship operating industry hope that we will be in a position to keep pace with technological advances, and to assist you to the utmost of our ability in your sea transport, provided we secure the support of the Canadian Government as outlined.

RESUPPLY IN THE SEVENTIES

BY: PERCY M. CROSBIE
PRESIDENT, CHIMO SHIPPING LIMITED

In looking forward to Arctic Transportation over the next decade we should really start by briefly looking back and reviewing developments over the last ten years.

During this short period of time there were three major developments in the Eastern Arctic.

1. The North Rankin Nickel Mine was brought into production and successfully shipped 20/30,000 tons of copper concentrate for several years from Rankin Inlet to Churchill, before the ore body gave out.

2. In 1965, the Asbestos Corporation commenced construction at Deception Bay and in the next two years moved in thousands of tons of construction materials and equipment. The project was temporarily shelved, but has now been activated and a turn key operation for their total construction program wil culminate in the shipment of asbestos fiber that is expected to be equal to or greater than any asbestos fiber mined to date in Canada.

3. New Quebec Raglan Mines Limited, a wholly owned Subsidiary of Falconbridge Nickel Mines Limited has been working about 35/40 miles Southeast and inland from Deception Bay. Their exploratory work to date has been so successful as to enable them to project that a full scale construction program will commence in the next two years.

Oil exploration in the Arctic is progressing at a growth rate so fast that the best prediction of the experts from only five years ago have been far exceeded. Carl Nickel, editor of the Daily Oil Bulletin, has been widely quoted as saying in a recent speech to the Air Committee of the Transport Ministry that Three Billion Dollars would be spent in Canada's northern oil exploration. This statement is borne out, in another way, by Charles R. Hetherington, President of Panarctic Oils Limited (as quoted in the Financial Post) "I have no doubt whatever that the real elephant of the Western Hemisphere is in the island and off shore areas of the Canadian Arctic and not in Alaska or the adjacent Canadian Mainland."

This effectively brings us up to the present, yet we have not mentioned one of the most important factors that will undoubtedly influence transportation in the '70's and, that is "Arctic Sovereignty." The reason for expressing our Sovereignty is, no doubt, very clear to all of us but the expression of this in a more tangable form produces added impetus for construction in the Arctic. The announcement at the end of October of a new town site to be constructed at Churchill - the increase of hotel/motel accomodations in Northern areas, for example, the 52 room expansion to The Eskimo Inn at Inuvik and the construction of the Frobisher Inn at Frobisher Bay - Regional Governmental control that now exists here in Yellowknife and secondarily at Frobisher Bay, with attendent home and office requirements, all these are signs of the times.

For purposes of clarification and discussion we would now like to define the general term "Canadian Arctic", and would suggest that to somewhat standardize the definition with the March 1969 Arctic Conference and to be able to relate to the insurance requirements, we would also consider Cape Dyer as the dividing line between the High Arctic and the Middle North.

Our personal experience to date based on recent trips into Eureka, an area previously served only by Canadian Government Icebreakers, has conclusively proved to us that only first class ice strengthened vessels can possibly service the area as will be required in the 1970's, and still guarantee the ecological protection to the area rightfully requested by our Government.

As a matter of fact, we would go one step further and categorically state that in our opinion, after having used ships of all sizes up to 10,000 deadweight tons for such projects as the Mid Canada Line and the Gap Pine Sites, we sincerely believe that vessels between 2,000/5,000 deadweight tons area are by far the best for resupply services. We would, as basis for this statement, ask you to consider the following points:

a. Smaller vessels can stand in closer to shore, thereby reducing towing time of barges between ship and shore.

b. One large vessel serving any given number of ports forces us to think on a "one call per season" basis, whereas with smaller type vessels, we can be more flexible and offer two or more sailings per port per season.

c. This "two calls per port" system becomes all the more important when manufacturers are unable to meet cargo delivery deadlines because, in our highly computerized industrial society, inventory control looms large in the eyes of the manufacturer who, therefore, becomes all the more susceptible to seasonal inventory demands; production delays on account of strikes; etc...

d. But the best reason of all for using two medium sized vessels instead of one large one is guaranteed delivery. Assume an engine breakdown, rudder malfunction, or cargo gear difficulties on the large vessel. Communities with cargo still on board the stricken vessel can actually be faced with their once a year cargo delivery being suspended and cargo returned to the original shipping port and then flown in, regardless of expense. But what happens if some of the cargo is too large for the planes capable of servicing the community in question. The cargo e.g. trucks, bulldozer, plow, etc. is put into storage and moved in during the next navigation season. This non-delivery of cargo is virtually eliminated when using smaller type vessels since one ship can back up the other.

While we have spoken at length of our own experimentation in cargo handling, we must not overlook the fact that according to the Canada Year Book, there are between 40,000 to 60,000 tons a year shipped into the North West Territories, which includes the resupply to the Dew Line, and this has mainly been done by time chartered ships in the 10,000 ton class supported by icebreaker and LCM and LST barges for transfer from ship to shore.

In 1969, the Department of Transport chartered the M. V. "SIR JOHN CROSBIE" to experiment with Skycrane discharge, and according to the after action report the experiment was very successful but also very costly. This year the Skycrane was used on the M. V. "FORT ST. LOUIS" which is an 8,365 ton gearless side loader and, although we have not seen the report on this experiment it seems it was very successful.

It is interesting to note that 1970 was the first time that a considerable amount of supplies were brought from Overseas into the High Arctic.

In 1968 and 1969 barges and tug boats were tried out in supplying the oil exploration industry in the High Arctic but it proved rather difficult for the tug to manoeuvre in heavy ice with barges in tow.

In our review of the past we have seen supplies being brought into Hudson Bay and the High Arctic and very little coming out. However, in the Seventies it is to be expected that asbestos will be shipped from Deception Bay and nickel concentrates from Douglas Harbour or Wakeham Bay, and if the oil exploration people are successful maybe oil from the High Arctic, however, due to the high cost of insurance we do not believe that it will be economical in the Seventies to ship low cost material such as iron ore from the Arctic.

We expect the transportation for the Seventies will be:

a. Resupply into Hudson Bay will be much the same as it has been over the last few years as there are so many small places to be served and not enough tonnage to warrant the cost of improved methods.

b. Outward cargo from the mines in Hudson Bay area will depend on destination of the products. If it goes to Canada it will most likely be in 15,000 to 20,000 ton size ships, but if for Overseas it will most likely be in Foreign Flag ships of 20,000 to 40,000 ton size.

c. Resupply for Dew Line Sites, Fox Basin, East Baffin and as far North as Resolute most likely will be accomplished by gearless ships with Skycrane discharge.

d. For the High Arctic, on cargo originating in or shipped from Canada, transportation in large measure will be done by small, highly manoeuvrable, first class ice strengthened vessels with heavy lift ship's gear which carries its own barges and tow boat, the tow boat operating on the same fuel as the mother ship. The ship being staffed with men experienced in both sailing and cargo handling and the cargo discharge from ship to barge and barge to beach will all be handled by ship's personnel.

e. If cargo originates from outside of Canada, it will most likely be in somewhat larger ships and discharge facilities will then have to be provided.

f. If, as we all hope, the oil exploration program is successful, the demand for supplies will, of course, greatly increase but until such a time that there is a fairly firm indication of oil in large quantities, it is not likely the shipping industry will invest too much money in new ships for this bulk trade, until further reports on the "MANHATTEN" experiment are available and also development on the use of pipeline on permafrost and maybe even bulk submarines have been examined.

THE USE OF HEAVY-LIFT HELICOPTERS IN EASTERN MARINE RESUPPLY

BY: J.W. STRATH, PRESIDENT, KENTING LTD.

Development of the high Arctic has precipitated an increased need for transportation systems that provide flexibility of operation, high reliability and utilization with economic justification.

For two years the Ministry of Transport has pioneered a system of replenishment that holds significant advantages for the development of remote Arctic areas and offers a viable solution to many problems encountered by the petroleum industry during exploration efforts.

In early 1969, the Department of Transport, Marine Division, began to evaluate the concept of deliverying cargo from ship to shore by heavy-lift helicopter in an effort to modernize the transportation system used for annual resupply of Arctic settlements.

Several factors led to this decision. First, because there are no ports or piers in the Arctic, the Division found themselves with a large inventory of landing craft, barges and other associated equipment used to transfer cargo from ship to shore. The costs of operating, maintaining and replacing this equipment was found to be very high. Second, the growth of the Arctic is placing a greater strain on the Department, more goods are being shipped northward, requiring more ships, more handling equipment and more manpower at increased costs. Third, because of the potential oil and gas deposits above the 60th parallel, time is a crucial factor in scheduling ships where the major hinderances to maintaining a replenishment schedule are ice floes, fog and high wind conditions

common to the polar regions.

This being the case, it was decided to determine if a better method of transporting and unloading vital supplies could be developed. The Marine Division studied new methods of lightering from vessels, evaluated ground effect machines and helicopters and came to the conclusion that the S-64 Skycrane helicopter offered the best potential.

In 1969, the first commercial application of the advanced concept was tested. A field trial to demonstrate and evaluate the feasibility of utilizing the Skycrane helicopters as the prime ship-to-shore cargo delivery vehicle was successfully conducted between July 30 and August 6.

More than 1,000 tons of containerized, palletized and bulk cargo was air-lifted from the motor vessel "Sir John Crosbie" and delivered to precise locations in the settlements of Cape Dorset and Coral Harbour. The total flight time involved in this off-loading operation was 34 hours and 16 minutes.

The field trial conducted in 1969 demonstrated to both the Government and industry that the helicopter delivery of cargo from ship to shore was operationally sound. Even under adverse conditions, cargo was delivered to precise locations on shore with speed efficiency and directness.

The system had eliminated time and cost consuming waits for barriers such as ice, tides, high winds and seas that stall normal re-supply. In addition, and very important to the analysis, the

cargo was delivered directly to construction sites or warehouse doors, minimizing multiple handling. Cargo damage during the airlift was much less than two percent, appreciably lower than recorded figures of 25 to 35 percent recorded by conventional discharge methods.

Due to the success of the 1969 trial a more extensive "systems approach" to resupply was organized and successfully executed during August of 1970.

The second test of the helicopter/cargo ship method of resupply was carried out during a 32 day trial of much greater magnitude. During the second test, the cargo vessel, the cargo and the Skycrane were viewed as an integrated system in an effort to obtain maximum effectiveness.

The cargo vessel used during the trial is a unitized package freighter owned and operated by Canada Steamship Lines. The configuration of the vessel lends itself readily to the system concept of unitizing cargo, freight discharge by helicopter and housing of the Skycrane and its support equipment, including fuel, on board.

The 3,000 tons of cargo aboard the vessel included busses, trucks, fuel, lumber and miscellaneous items ranging from refrigerators to bedsprings. Where possible, the loads were assembled in lots weighing up to 18,000 pounds to take advantage of the full capacity of the Skycrane. Cargo was packaged in gondolas or pre-slung with steel cable for the airlift.

The helicopter was based on the vessel during the entire voyage, eliminating the expense of ferrying the aircraft from Stratford, Connecticut to the area of operations. In 1969, the S-64 flew over 2600 miles, ferrying between Stratford and Cape Dorset-Coral Harbour.

Cargo was discharged to inland distribution points (some, six miles away from anchorage) at an overall average of 40 tons per flight hour. Eighteen working days were required to discharge all of the cargo.

At each port of call the Skycrane established some very impressive records. At Resolute Bay, 900 tons of cargo were discharged in five days, including three days when dense fog and ice floes jammed the harbour. The S-64 delivered cargo to eight different locations, with the majority of loads being delivered inland six miles to the airport warehouse complex.

At Arctic Bay, 300 tons of cargo were delivered in five flight hours over a radius of one mile from ship to shore, for an average of 60 tons of pure cargo delivered per hour. The ship was in and out of port in less than 24 hours.

At Pond Inlet, 551 tons were delivered in less than two days. At Clyde River, the S-64 carried 695 tons of material from ship to shore and 22 tons of retrograde were airlifted back to the ship.

Over four hundred tons were airlifted to three sites as far as six miles inland at Frobisher Bay to complete the trial.

During the 32 day period that the ship was away from Montreal a total of 2,862 tons of pure cargo had been carried by the helicopter from ship to shore. When possible the cargo was flown directly to warehouse doors or construction sites minimizing the need for multiple handling.

Cargo damage was estimated to be less than one percent for the entire operation.

Extremely important is the fact that the Skycrane performed cargo discharge operations when all other methods would have been halted. Cargo was delivered over ice packed harbors, in rain and fog and in winds up to 50 mph.

The Arctic demands flexibility of transportation systems not only to move massive tonnages from ship to shore where ports are not available - but inland over terrain where roads do not exist. It seems that the last 10 miles or so are always the most difficult to negotiate. For example, supplies brought by ship or airplane from the south can always be marshalled on the beach or beside a gravel landing strip - but what about the last 10 to 15 miles distance from the marshalling area to the drill site? What about the movement of rigs from one place to another? The cost of transporting this material is exorbitant and the timing is essential.

What better way to minimize the excessive costs, save time, and eliminate many of the logistic problems experienced in previous programs than to airlift the material directly to the drilling site.

To improve the operating economies of a heavy-lift helicopter in the Canadian Arctic greater utilization must be gained than that available solely from ship off-loading. In this regard, helicopter manufacturers and operators will have to show potential users how this vehicle can save them time and money in their search for mineral wealth.

The Skycrane was very active on the North Slope of Alaska in 1969 just prior to the land sale. Two aircraft, operated by Rowan Air Cranes flew nearly 1,000 hours during a three month period and delivered 12,000 tons of supplies during exploratory drilling operations at Prudhoe. Distances covered exceeded 30 miles one way.

In conclusion, we have heard about a rather unique system of cargo delivery - and soon we'll see a movie of the system in action. The concept offers many advantages to exploration and development in the Arctic and the Ministry of Transport should be congratulated for pioneering the Sea/Air System.

VOLUME 2

SECTION 3 - NORTHERN ROADS, TRUCKING AND OFF-ROAD TRANSPORTATION

CHAIRMAN: John Parker

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"It is a rough road that leads to the heights of greatness".

Seneca

NORTHERN ROAD PROGRAM

BY: H.W. WOODWARD

Northern Economic Development Branch
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Introduction

The Territorial Road Policy and the Northern Road Program, formulated in detail in 1958, concerns the development of a road system to serve both the Yukon and Northwest Territories. The Northern Road Program is a part of the Road and Airport Sub-Activity of the Department of Indian Affairs and Northern Development.

Prior to 1940, only a few isolated, short road segments existed in the Canadian North. These had been built to serve the needs of local communities and to connect the nearest water transportation routes. Interconnection between communities was achieved by water or wagon in the summer, and by dog sled or horsedrawn sleigh in the winter. The need for an interconnecting road network in the north was not emphasized.

In the early 1940's, construction of the Alaska Highway to provide a road link between the airfields of the Northwest Air Staging Route to Alaska, established 625 miles of road within the

Yukon Territory and provided road links with southern Canada and the Pacific Ocean at Haines, Alaska. The Northwest Territories was linked by road to southern Canada, with the construction of the Mackenzie Highway in 1949, over a distance of 470 miles between Grande Prairie, Alberta and Hay River. In 1951, a road was completed from Whitehorse to the United Keno Hill silver mine near Mayo, and in 1955 a road was constructed between Stewart Crossing and Dawson.

As early as 1951, the Interdepartmental Committee on Federal Territorial Financial Relations had developed a simple classification for all roads in the territories and allocated responsibility for construction and maintenance of roads in each category. This was elaborated on in 1957. However, it was only during the period of the 1957-62 Federal-Territorial Financial Agreement that the Northern Development Road Program was introduced to meet the attendant need for a more detailed and more precisely defined road classification, road construction standards and a new allocation of financial responsibilities. In October, 1958, the Prime Minister in an address to the Canadian Good Roads Association said: "Over the next six to seven years, the Federal Government will invest upwards of $100 million on development roads in the two territories. Existing roads such as the Mackenzie Highway, the Alaska Highway, and the Whitehorse-Dawson road are being used as points of departure. From these, new roads will be pushed into areas which, according to the best technical appraisal available, present the most favourable prospects for development."

To date, more than 3,000 miles of road have been built in the two territories, and although the mileage is small in relation to the size of the territories, the contribution that the territorial road system has made to the development of the Canadian North and the economic well-being of its residents is important.

In the following, discussion is given to the evolution of the Territorial Road Policy and to the development of the Northern Road Program.

Territorial Road Policy

The Territorial Road Policy, as modified in 1962, is set out in a paper accompanying the reports on Federal-Territorial Financial Relations for the Yukon and Northwest Territories. The paper divides roads in the territories into two main classifications; Communication Roads and Resource Roads.

"Communication Roads" are those highways, major roads, secondary and local roads, exclusive of roads facilitating resource development, which provide a primary network of roads for communication within the territories, including north-south connecting links with the Provinces and east-west connecting links between the territories. The categories of roads under Communication Roads are: (i) Trunk Highways; (ii) Secondary Trunk Roads; (iii) Airport Roads; and (iv) Local Roads. The Territorial Government is responsible for the construction of Local Roads and the Federal Government for all other categories of Communication Roads.

"Resource Roads" are those roads which lead from a communication road to a location where promising mineral or other

natural resources and considered to exist. The categories of roads originally established under the classification of Resource Roads were: (i) Area Development Roads, to be developed by the Federal Government on the basis of the resource attractiveness of the area; and others to be developed in partnership with industry included; (ii) Mine Development Roads; (iii) Mine Access Roads; and (iv) Tote Trails. Assistance to companies and individuals with respect to Tote Trails was provided by the Territorial Governments from a total annual allotment of $50,000 to each for this purpose.

The policy as modified in 1962 emphasized the building of roads in order to encourage resource development, particularly mining, and, to a lesser extent, oil and gas; also it accepted the concept that roads should be extended into areas with good resource potential prior to extensive exploration. The proposed policy was clear and well designed but no long range plan of construction or rate of expenditure were approved at the time. Consequently, the roads built in each of the subsequent years were determined largely on an 'ad hoc' basis, and as a result, the expenditures proposed were subject to a downward revision during each estimate review.

In 1965 the Northern Road Program was re-examined and a position paper entitled 'A Northern Road Policy for the Future' was prepared, reviewing road construction in the north to that date, and suggesting that the existing policy should be modified. The paper outlined a road construction plan for two consecutive 10-year periods and submitted an acceptable level of expenditure on new road construction (Tables I and II).*

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* All Tables and Figures follow the text.

Like former versions of the Territorial Road Policy, the position taken in the paper continued to recognize the need of roads both for the development of communities and resources, but in particular it emphasized the ultimate need for development of a network of roads, and specifically made additional provision for roads to be built jointly with industry. The network proposed was designed to consist of a series of loops which would limit the distance between a resource project and a permanent road to 200 miles. It was considered that the road network would ultimately provide north, south, east and west transportation, gradually replacing seasonal water transportation, reducing transportation costs, and achieving a measure of cost equalization with southern Canada.

The current Territorial Road Policy and current Northern Road Program was adopted in September, 1965, following Cabinet approval, and implemented in the following year, 1966-67. The policy recognizes several categories of roads which, briefly summarized*, are:

1. Communication Roads and Network Roads:

   i) Trunk Highways: - Roads of high construction standards which provide connecting links between the territories and the southern part of the country, or between the principal centres of population within

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* Minimum Desirable Construction Standard for these Categories is given in Table VI.

the territories and which, from their inception, can be expected to carry a significant density of traffic. Paid for by the Federal Government.

ii) Secondary Trunk Roads: - Roads designed to carry a lower density of traffic and built to lower construction standards than trunk highways. They may provide connecting links of secondary importance between the territories and the southern part of the country or between centres of population; or, as "pioneer trunk roads", extend the basic territorial roads network into undeveloped areas where it is reasonable to expect a requirement for "Resource Roads". Paid for by the Federal Government.

iii) Airport Roads: - Roads which connect the property boundary of approved public airports on land or water with the nearest local or other public road. Paid for by the Federal Government; and

iv) Local Roads: - Roads within a community or municipality. Paid for by the local or the territorial government.

2. Lateral (Resource) Road:

i) Area Development Roads: - Roads of relatively low construction standard into or through an undeveloped

region of favourable natural resource potential for the purpose of fostering new growth in the economic activities of the territory. Paid for by the Federal Government.

ii) Resource Development Roads: - Roads which lead from the nearest permanent road into an area in which two or more resource projects have reached the Pre-Production Stage. Paid for by the Federal Government.

iii) Permanent Access Roads: - Roads which lead from the nearest permanent road to the location of a resource development which has been brought to the beginning of the Pre-Production-Production Stage. Paid in an amount by the Federal Government up to, but not to exceed: 66-2/3 per cent of total cost, or 15 per cent of actual capital invested by the company prior to commencement of commercial production or exploitation, or $40,000 per mile -- the balance paid by the resource developer.

iv) Initial Access Roads: - Roads which are low standard and provide temporary, seasonal, or year-round access to the property of a company engaged in exploring or developing a natural resource where, because of length, terrain, or difficulty of construction, total cost is such that a contribution

under the Tote Trail category would be insufficient. Paid in an amount by the Federal Government up to but not to exceed: 50 per cent of total cost, or 5 per cent of expenditure, or $100,000 in one year if the project is primarily exploratory in nature, of $500,000 in one year if the project is primarily developmental in nature -- the balance cost-shared by the resource developer.

v) Tote Trails: - Roads which are low standard and provide temporary, seasonal, or year-round access to a company engaged in exploring or developing a natural resource. Paid in an amount by the Territorial Government up to, but not to exceed 50 per cent of total cost, or 5 per cent of expenditures to be made by the company for exploration and development, or $20,000 -- the balance cost-shared by the resource developer.

Approval of the revised Territorial Road Policy and Northern Road Program recognized particularly the objective of establishing a systematic and long-term road construction plan and devoting a firm level of expenditure for new road construction which should not be subject to reduction without a consideration of the consequences to the overall program. Specifically, confirmation was given to the ten year road network plan (to be regarded as flexible and subject to adjustment to meet changing conditions); to the rate of annual expenditure for new road construction of $10,000,000

(expenditure for maintenance, realignment, major bridges and paving to be considered as separate projects and not included in the new road construction expenditure); and to an increase in the federal grant to each territory for Tote Trail purposes from $50,000 per annum to $100,000 per annum.

Northern Road Program

As a consequence of the evolving territorial road policies, the rate of expenditures on road construction increased during the late 1950's from an average annual expenditure of less than one million dollars in the first half of the decade to over five million in the last half, with a relative increase in the number of miles of road constructed (Figures 1 and 2).

The tentative plan of road construction drawn up in 1958 when the Territorial Road Policy was first introduced was approved in principle only, although the 1959-60 portion of the program was specifically approved and confirmed. As a consequence of stringent government economies in the first half of the 1960's, annual expenditures on northern road construction and the number of miles completed each year dropped remarkably, and recovered only with the adoption in late 1965 of the revised Policy and commitment to a new 10-year, $100 million construction program.

Expenditures by the Federal Government on roads in the territories to the end of 1970 total almost $150,000,000; approximately 70 per cent has been expended in the Yukon Territory and

30 per cent in the Northwest Territories. Division of expenditures between the territories has been determined by the needs of the Canadian North as a whole rather than by some arbitrary formula. In recent years expenditures between the territories have equalized. Possibly by 1985, if the proposed road programs are implemented, the aggregate expenditure in the Northwest Territories will exceed that in the Yukon, reflecting the larger area of the Northwest Territories.

Since the start of the current Northern Road Program in the fiscal year 1966-67, approximately $42,000,000 has been expended on the construction of approximately 700 miles of new road. The status of the Program to the end of 1970 is given in Table I. Two projects originally proposed in 1965 for the second ten-year road program, Table II, included the road from Inuvik to Arctic Red River, and between Arctic Red River and Fort McPherson, have been brought forward and will be placed under construction in 1971. A new project, the road between Pine Point and Fort Resolution, has been incorporated into the Program and construction has begun.

The Program has been augmented by 450 miles of resource roads, and by bridges constructed by private resource developers with up to two-thirds costs shared by the Federal Government, and almost 2,200 miles of tote trail have been opened. To date, almost $3,000,000 has been granted in assistance payments under the Program (Table III).

A summary of expenditures on road construction made to the end of 1970 and proposed to the end of 1975 under the current Northern Road Program is listed in Table IV. All road projects completed, underway, proposed, and possible (Second ten-year program), are shown in Figure 3.

Each year there has been an increase in the expenditures on reconstruction of existing roads in the two territories. This is largely attributable to the need to upgrade the roads, both by widening and by improving subgrades, and to accommodate an increase in volume of traffic and in the weight of vehicles using the road. Financing reconstruction from the $10 million annual capital budget for the road program has reduced the number of miles of new road. Thus, if the capital budget should remain fixed, construction of the road network proposed in the first 10-year plan will not be attained.

With the exception of cost-shared roads which are maintained by the private developer, the cost of maintenance of all northern roads is shared by the Federal Government and appropriate Territorial Government on a ratio of 85 per cent to 15 per cent respectively, and is outside of the budget for the Northern Road Program. In the case of road wholly financed by the Federal Government, contractors are held responsible for the maintenance of the road or portion of the road which they have contracted to build until the contract has been completed and the road has been

turned over to the appropriate Territorial Government. Except for new local roads, or a road reclassified as local road, the Territorial Government is not required to contribute its 15 per cent toward maintenance until the date on which the next Federal-Territorial Financial Relations Agreement comes into effect following the official completion of the road. Cost of road maintenance, including grading, snow removal, sanding, ditching, resurfacing, culvert and bridge maintenance and other work necessary to keep the northern roads to their originally designed or subsequently improved standards, and provide safe travelling conditions for the general public, increase as the road network increases and extends further north into more difficult terrain (Table V).

Administration, Planning and Priorities

The Northern Road Program is managed by the Department of Indian Affairs and Northern Development under the guidance of an intra-departmental Committee, (Northern Road Administrative Group), which includes principally representatives of the two territorial governments, the Territorial Relations Branch the Technical Services Branch, and the Northern Economic Development Branch. A section within the Northern Economic Development Branch prepares relevant construction schedules and provides day-to-day administration. The Program is implemented through the services of the Technical Services Branch in co-ordination with similar agencies of the Department of Public Works and of each of the Territorial Governments by contracts awarded to private companies by public tender. The

Intradepartmental Committee makes recommendations with respect to applications for Federal assistance of cost-shared resource roads. Each application is carefully evaluated by technical officers in the Department to determine the benefits that could accrue to the Crown and the territories before any financial assistance is recommended.

Early experience in the administration of the Northern Roads Program indicated that the amount of money actually spent in any one year was less than the amount committed for expenditures. Reasons cited were weather, transportation difficulties, and the delay in establishing contract claims, which must be reconciled with unit charges. Most of these difficulties have been overcome by improved planning and advanced surveys; others are being overcome by the use of early tender calls and longer term contracts stretching over two or more years.

An interdepartmental Committee (Advisory Committee on Northern Roads) comprised of senior advisers in the fields of geology, engineering and finance has b-en established to advise on the appraisal and planning of Area Development Roads and to recommend priorities in order of construction.

The road network proposed in the current 10-year Northern Road Program, and tentatively forecast in the second 10-year program, suggests the most desirable road network on the basis of present information and trends. Although individual road segments may be expected to conform generally with this outline, the order in which segments might be constructed and the actual outline at the end of the 10-year program and successive programs will depend upon annual decisions on the basis of the best available information

and advice regarding access to resources, and upon rapidly changing social, educational, commercial, tourist and other needs which must be served by a dynamic and flexible road policy. In interpreting and implementing the policy, priorities for construction of roads take into consideration such factors as:

i) the density of traffic expected to use the road;

ii) the resource potential and probable development capacity of the areas to be opened by the road;

iii) the value of goods expected to be moved over the road in relation to costs of the road;

iv) the potential public use of the roads; and

v) the effect on local employment and economic conditions that might result from the construction, maintenance and availability of a road or roads.

A most important feature of the management of the Program is close liaison which must be maintained with northern residents, business interests and organizations in order to ensure the road programs are fulfilling the intent of the policy and meeting the needs of both community and resource development. Accordingly, it is the practice of the Northern Road Administrative Group and the Interdepartmental Advisory Committee on Northern Roads to meet jointly in each of the territorial capitals once each year. The Minister and senior officials of the Department of Northern Development are in constant contact with officials and people of each of the territories on many matters of northern development, not the least of which is the Program on northern roads.

In May 1967, one year after initiation of the current Program, a Road Appraisal Committee consisting of members of the Northern Roads Administrative Group made a 3-week tour of the North to seek opinions and advice from local business interests and organizations with respect to:

i) the routes the territorial network of roads should follow and the priorities that should be alloted;

ii) road construction and maintenance generally including such items as road reconstruction, paving and major bridge construction which do not form part of the 10-year, $10-million annual program the Northern Roads Policy covers; and

iii) the adequacy of the Territorial Roads Policy itself.

In its widely distributed report, the Fact Finding Committee made a number of recommendations some of which, if implemented, would involve major capital expenditures over and above the level approved by Cabinet in 1965. Consequently, action is being taken upon those recommendations which are non-financial in nature, including:

i) modification of the Policy to include provision for low standard access roads, for low standard communication roads ten years ahead of their planned construction as primary network roads, and for the construction and operations of winter roads;

ii) the granting of authority for the Departmental officials to conduct continuing informal discussions

with officials of the Government of Alberta, of the Government of British Columbia, and the State of Alaska relative to the establishment of border crossing points for possible future connecting roads and other technical matters;

iii) the possibility of cost sharing with the provinces concerned, the construction of the Carcross-Skagway, the Fort Simpson - Fort Nelson, and the Fort Smith - Uranium City routes;

iv) a continuing review of the merits of construction bridges across the Yukon River at Dawson and the Mackenzie River at Fort Providence (outside the purview of the Northern Road Policy) so that these are constructed as soon as the situation warrants; and

v) the practice of a fact-finding tour in connection with Northern Roads Program to be continued on a bi-annual basis.

The report of the Road Appraisal Committee and the advice received from all other groups and individuals interested in the development of a road network in the Canadian North continue to be extremely important in guiding the Northern Road Program.

Northern Road Program Forecast

Construction Priorities:

Approximately 50 per cent of the expenditures on new roads

under the Northern Road Program are scheduled for construction of the Dempster Highway and the northern segment of the Mackenzie Highway to provide a road connection of the road network of the southern Yukon with Inuvik, Northwest Territories by the end of 1974. This priority program will prove most timely for the probably construction of a large gas pipeline from Prudhoe Bay field in northeast Alaska in its proposed segment across the central Yukon, and for the concommitant escalation of oil and gas exploration in the central Yukon and Mackenzie River Delta sedimentary basins, and subsequently for the development there of oil and gas pools. Shortening of the time frame for construction of the Dempster Highway has unfortunately drawn capital from other road projects which consequently must be deferred unless additional capital expenditures under the Northern Roads Program are authorized in future Estimates.

Pioneer Roads:

Action is being taken to establish provision for low standard roads designed to provide access into undeveloped areas of favourable natural resource potential and to outlying population centres in a reasonably short period of time where, normally the construction of higher standard network roads would not be planned for a number of years in the future. Included in this general 'pioneer road' category will be winter roads.

In this respect $20,000 was granted to Western Electronics Limited in 1969 and $100,000 in 1970 to assist in the construction

and operation of a winter road from Fort Simpson to Inuvik -- Essentially the road has been operated, first by Calex Exploration Limited 1964-1968, and by Western Electronics 1969 and 1970, as a public utility with a nominal levy to private users at a rate not greater than 4.0 cents per ton-mile. To a similar end assistance under the tote trail program has been provided to Byers Transport who have established a winter tractor road connecting Yellowknife and the mines at the east end of Great Bear Lake. Probably the Government should provide such road where need warrants and where private enterprise cannot, or will not, do so because costs cannot be recovered.

Dust Control:

The highway traffic generated by such mining developments as Cassiar Asbestos Corporation at Clinton Creek near Dawson, and at Cassiar, B.C., and by the Anvil Mine at Faro, has raised a need for more adequate dust control measures for northern roads The dust conditions are a grat nuisance where roads pass through or near communities, and are an inconvenience and serious hazard to all road travellers. Although expenditures for dust control on existing highways come under the category of 'maintenance', projects for dust abatement were initiated in 1969 with the incorporation of calcium chloride with crushed gravel in the two-year surfacing contract in respect of the Campbell Highway between Carmacks and Ross River. Comparative study of the results of this method of application of calcium chloride with that of conventional application of this dust pallative in the Klondike Highway, south of Carmacks has not been concluded.

Paving:

The cost of paving northern roads has not been justified in the past on a strictly economic basis, however social requirements have necessitated paving of small segments. Paving of the Alaska Highway over a 24-mile stretch adjacent to Whitehorse was initiated in 1969 and will be completed this year. Paving of northern roads within communities may be expected to become a reasonably common 'local elective' in the future under cost sharing arrangements between municipalities and the Territorial Governments.

Road Standards, Load Limits:

The roads in the territories are constructed according to the road standards established for the particular road under construction, considering its use, anticipated traffic and other related factors (Table VI). At the present time the trunk road from Alaska Highway (Whitehorse) to Carmacks and thence to Faro is authorized to carry loads to 95,000 lbs. G.V.W. or 42,000 lbs. maximum tandem axle loading - other territorial roads including segments of the Alaska Highway are authorized to carry considerably less. Recently there have been a number of requests to approve increased loading on other roads leading to Whitehorse. Accordingly, an assessment of the costs to improve the strength of bridges on the appropriate routes and of relocation, reconstruction and of upgrading road segments to bear increased loads is underway. These costs will be considered in comparison with possible benefits from increased loading both to the private developer and to the territorial economies before a decision is made on this matter.

Major Bridge Construction:

Expenditures for major highway bridges in the north are considered as separate projects and are not included in the budget for Northern Road Program approved in the Territorial Road Policy. However, as these are an integral part of a northern road system, cost-benefit analyses of a bridge over the Mackenzie River at Fort Providence, and over the Yukon River at Dawson, are now underway and expenditure for construction of these are tentatively identified in the Departments capital programs five-year forecast.

At present both crossings are served by ferries in the summer and by ice-bridges in the winter. During the periods of spring break-up and freeze-up, which may last as long as three months in total each year, traffic over the rivers ceases with the exception that a skyline is operated at the river crossing at Dawson to transport people and limited cargo. With the establishment of Yellowknife as the capital of the Northwest Territories, requirements for a bridge over the Mackenzie River have increased steadily. Similarly, the bringing into production of the Clinton Mine of Cassiar Asbestos Corporation Limited has brought about increased demand for a bridge at Dawson. Decisions on the construction of these bridges may be reached next year.

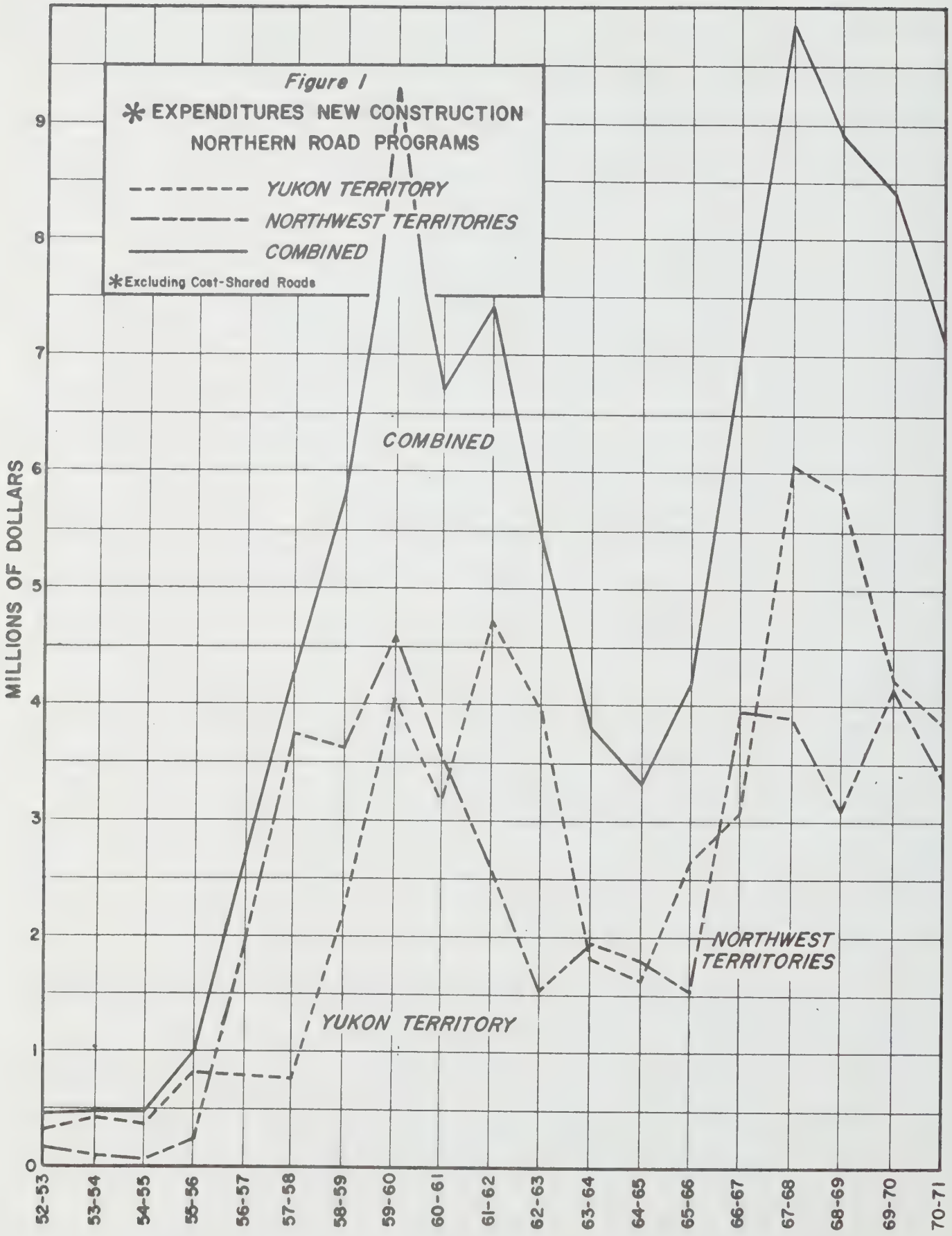
Territorial-Provincial-International Road Connections:

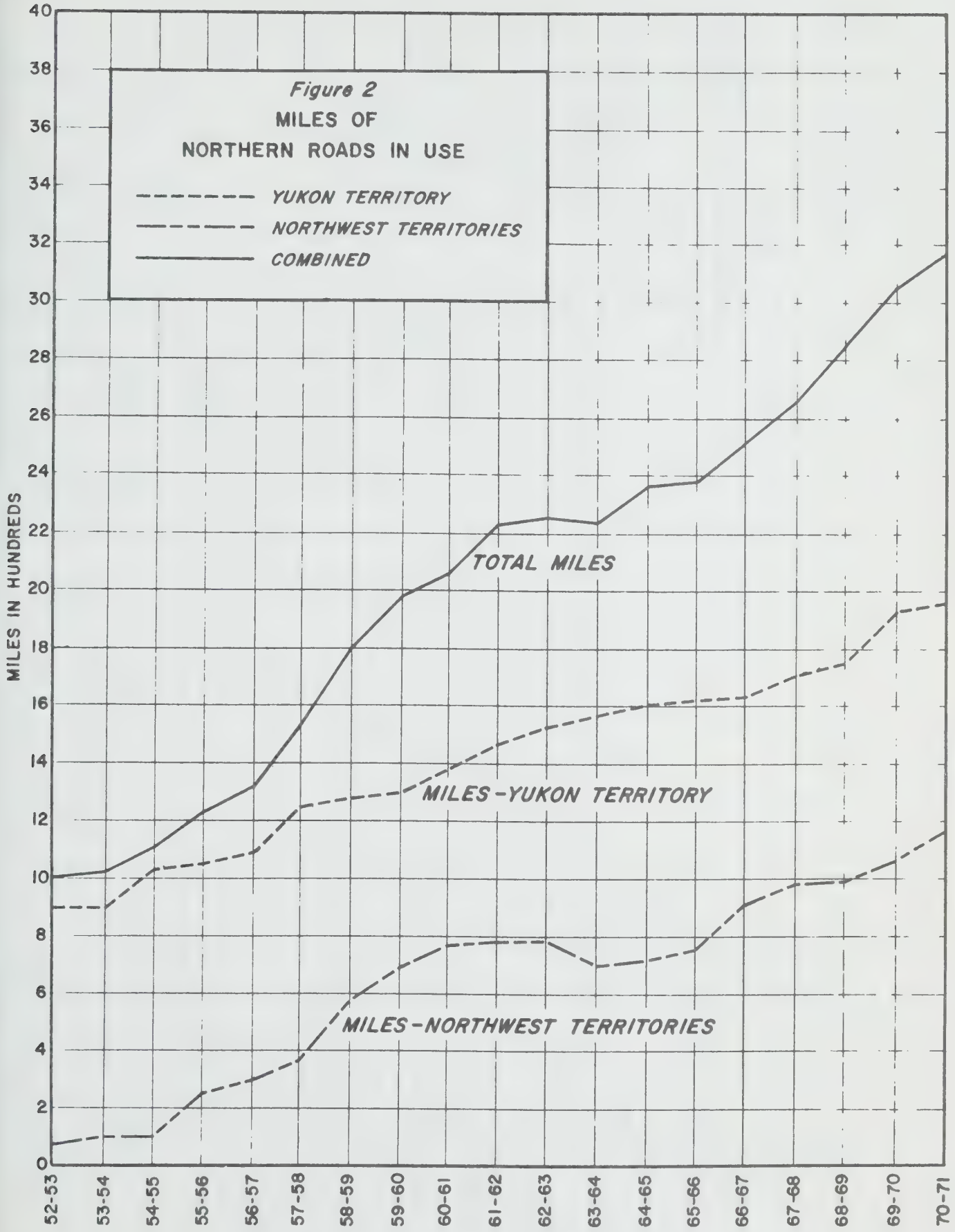
In order to achieve the ultimate aim of improved transportation facilities in the North, it is essential that roads built within the Territories in the vicinity of the 60th parallel tie in with existing and future roads in the provinces or in

Alaska. Preliminary and in some cases unofficial discussions have been held in respect of proposed roads from Fort Smith to Fort McMurray in Alberta, from Fort Simpson to Fort Nelson in British Columbia, and from Carmacks to Skagway in the Alaskan Panhandle -- and the means are being put forward to provide for more formal presentation to effect possible road inter-connections.

Conclusions

The present Territorial Road Policy and the successive Northern Road Programs have played a significant part in the economic development of the North, particularly over the past ten years. Current and near future requirements for new roads, major bridges, dust control and other projects relevant to the development of a road network adequate for the forecast levels of economic development of each of the Yukon and Northwest Territories can be identified. Justification for the relevant high annual expenditures to provide for these, however, is not to be found only in individual project cost-benefit analysis, but more rationally within the context of an integrated northern transportation study, or more broadly in a Strategy for Northern Development.


Figure I
* EXPENDITURES NEW CONSTRUCTION
NORTHERN ROAD PROGRAMS
YUKON TERRITORY
NORTHWEST TERRITORIES
COMBINED
*Excluding Cost-Shared Roads
MILLIONS OF DOLLARS
0
1
2
3
4
5
6
7
8
9
COMBINED
NORTHWEST TERRITORIES
YUKON TERRITORY
52-53
53-54
54-55
55-56
56-57
57-58
58-59
59-60
60-61
61-62
62-63
63-64
64-65
65-66
66-67
67-68
68-69
69-70
70-71


Figure 2
MILES OF
NORTHERN ROADS IN USE
YUKON TERRITORY
NORTHWEST TERRITORIES
COMBINED
MILES IN HUNDREDS
TOTAL MILES
MILES-YUKON TERRITORY
MILES-NORTHWEST TERRITORIES
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
52-53
53-54
54-55
55-56
56-57
57-58
58-59
59-60
60-61
61-62
62-63
63-64
64-65
65-66
66-67
67-68
68-69
69-70
70-71

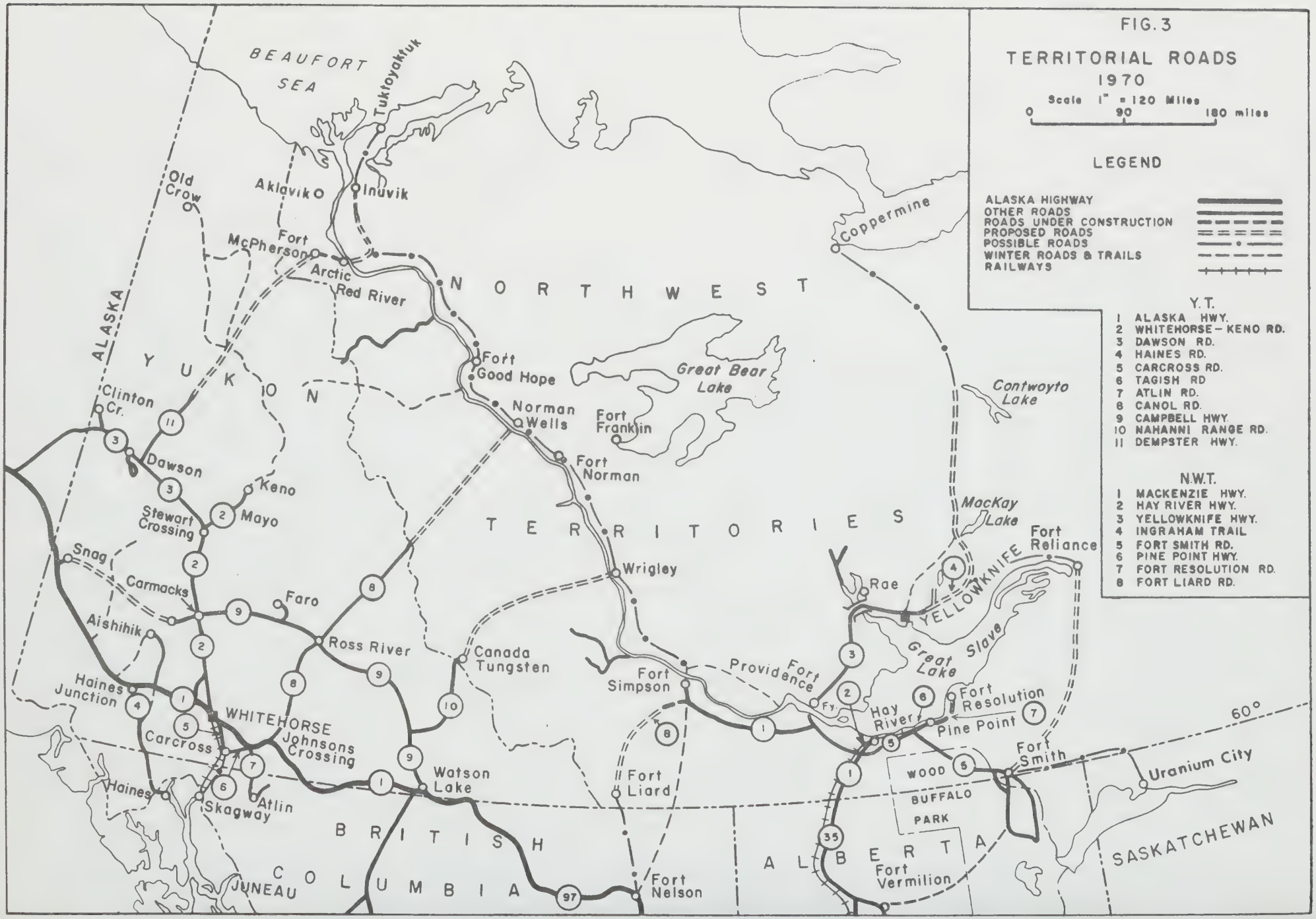

FIG. 3
TERRITORIAL ROADS
1970
Scale 1" = 120 Miles
0 90 180 miles
LEGEND
ALASKA HIGHWAY
OTHER ROADS
ROADS UNDER CONSTRUCTION
PROPOSED ROADS
POSSIBLE ROADS
WINTER ROADS & TRAILS
RAILWAYS
Y.T.
1 ALASKA HWY.
2 WHITEHORSE – KENO RD.
3 DAWSON RD.
4 HAINES RD.
5 CARCROSS RD.
6 TAGISH RD
7 ATLIN RD.
8 CANOL RD.
9 CAMPBELL HWY.
10 NAHANNI RANGE RD.
11 DEMPSTER HWY.
N.W.T.
1 MACKENZIE HWY.
2 HAY RIVER HWY.
3 YELLOWKNIFE HWY.
4 INGRAHAM TRAIL
5 FORT SMITH RD.
6 PINE POINT HWY.
7 FORT RESOLUTION RD.
8 FORT LIARD RD.
BEAUFORT SEA
Tuktoyaktuk
Inuvik
Aklavik
Old Crow
Fort McPherson
Arctic Red River
ALASKA
YUKON
NORTHWEST TERRITORIES
Coppermine
Contwoyto Lake
Great Bear Lake
Fort Good Hope
Norman Wells
Fort Franklin
Fort Norman
Clinton Cr.
Dawson
Keno
Mayo
Stewart Crossing
Snag
Carmacks
Faro
Aishihik
Ross River
Canada Tungsten
Wrigley
Fort Simpson
Fort Providence
Rae
MacKay Lake
Fort Reliance
YELLOWKNIFE
Great Slave Lake
Hay River
Fort Resolution
Pine Point
Haines Junction
WHITEHORSE
Carcross
Johnsons Crossing
Haines
Skagway
Atlin
Watson Lake
Fort Liard
Fort Smith
Uranium City
60°
WOOD BUFFALO PARK
ALBERTA
Fort Vermilion
SASKATCHEWAN
BRITISH COLUMBIA
JUNEAU
Fort Nelson

TABLE I

STATUS, NEW CONSTRUCTION, NORTHERN ROAD PROGRAM, 1966-75

st 10-year Plan

d	Distance (miles)	Cost to Date ($,000)	Status end 1970
s River-Carmacks	142	9,060	completed
macks-Snag	120	---	not started
oster Highway apman Lake-Fort herson)	200	2,122	15% completed
ol Road - Y.T.	125	585	completed to minimum standards
ol Road - N.W.T.	195	---	not started
kenzie Highway terprise to Fort pson)	179	8,400	completed
t Simpson-Fort rd and B.C. border	172	1,314	15% completed
e Point-Fort Smith	120	714	completed
t Smith-Fort iance	270	---	not started
lowknife - Kay Lake	183	1,506	25% completed
Kay Lake-Contwoyto e	150	---	not started
raham Trail - don Lake	35	---	not started
e Point - t Resolution		191	% completed
tic Red River-Inuvik		108	surveyed
tic Red River - t McPherson		111	surveyed

TABLE II

TENTATIVE, NORTHERN ROAD PROGRAM, 1976-1985
(as proposed in 1965)

Second 10-year Plan

Location	Distance	Estimated Cost $
Fort Simpson - Wrigley	150	10,000,000
Wrigley - Norman Wells	180	11,000,000
Norman Wells - Arctic Red River	275	18,000,000
Arctic Red River - Inuvik *	80	5,000,000
Inuvik - Tuktoyaktuk	70	4,000,000
Arctic Red River - Fort McPherson *	25	1,500,000
Fort Smith - Talston River	60	3,000,000
Talston River - Fort Reliance	200	10,500,000
Fort Reliance - Wolverine Lake	90	5,000,000
Fort Smith - Uranium City	125	6,000,000
Northern Parks roads	160	8,000,000
Lateral (Resource) roads	N/A	20,000,000

* Moved forward to 1966-75 program.

TABLE III

EXPENDITURES, COST-SHARED RESOURCE ROADS,
NORTHERN ROAD PROGRAM, 1966-75

oject	Miles of Road	$ 1966-67	$ 1967-68	$ 1968-69	$ 1969-70	$ est. 1970-71
rmanent Access ad		(515,000)*				
ssiar Asbestos	26	137,117	---			
nada Tungsten	35	69,773	---			
v Imperial	2	43,300	---	8,841	---	
vil Mining orp.	18		381,668		562,332	720,606
ctic Gold & ilver	8			100,000		
itial Access ad						
noe River	170			44,381		
nus Mines	16				115,000	41,680
Ray McDermott	150				50,000	
unt Nansen	23				50,000	
te Trail						
kon Territory	1,538	81,940	98,750	98,911	80,084	80,000
rthwest rritories **	662	4,863	1,250	67,652	71,033	70,000
T O T A L S		336,993	481,668	319,785	928,449	912,286

(515,000) Assistance payment in 1965-66

Include $ contribution for ploughing winter roads.

TABLE IV

EXPENDITURES CONSTRUCTION NEW ROAD, NORTHERN ROAD PROGRAM, 1966-76

(Actual and Proposed, $'000)

Year	Yukon Territory	Northwest Territories	Cost-Shared Resource Roads	Total
1966-67	3,063,308	3,968,225	336,993	7,386,526
1967-68	6,046,903	3,815,058	481,668	10,343,629
1968-69	5,820,100	3,133,000	319,785	9,273,785
1969-70	4,284,566	4,177,102	928,449	9,390,117
1970-71(est)	3,797,000	3,332,000	912,286	8,041,286
1971-72(est)	3,473,000	8,165,000	1,500	11,639,500
1972-73(est)	4,750,000	8,150,000	1,250	12,901,250
1973-74(est)	4,240,000	8,220,000	1,250	12,461,250
1974-75(est)	3,150,000	9,020,000	1,250	12,171,250
1975-76(est)	4,650,000	8,200,000	1,250	12,851,250

TABLE V

EXPENDITURES ON NORTHERN ROAD MAINTENANCE BY FEDERAL GOVERNMENT

(Generally 85 per cent of Total Costs, $000)

	1966-67	1967-68	1968-69	1969-70	1970-71
Yukon Territory	1,157	1,121	1,344	1,184	2,042
Northwest Territories	770	828	603	675	1,067

TABLE VI
MINIMUM DESIRABLE ROAD STANDARDS (1)

TYPE	DESIRABLE DESIGN SPEED	WIDTH OF RIGHT OF WAY	WIDTH OF TRAVELLED SURFACE	WIDTH OF SHOULDERS (each)	BRIDGE DESIGN	BRIDGE WIDTH & HEIGHT	MAXIMUM GRADE	MAXIMUM CURVATURE
Area Development Road	50 m.p.h.	100'	18' (3)	3'	H20-S16	24'&14'6"	10%	20°
Permanent Access Road	50 m.p.h.	100'	18' (3)	3'	H20-S16	24'&14'6"	10%	20°
Initial Access Road	25 m.p.h.	50'	12' Min. with turn-outs	nil	H20-S16	12'&14'6"	14%	35°
Resource Development Road	50 m.p.h.	100'	18' (3)	3'	H20-S16	24'&14'6"	10%	20°
Tote	Tote Road may be constructed to whatever standard that will provide suitable access to property of individual (4)							
Trunk	60 m.p.h.	150'	24'	4'	H20-S16	28'&14'6"	5%	7°
Secondary Trunk	40 m.p.h.	70'	18'	2'	H20-S16	24'&14'6"	12%	14°
Airport	30 m.p.h.	70'	18'	2'	H20-S16	24'&14'6"	12% (5)	14° (6)
Local	30 m.p.h.	100' or full dedicated right of way	18'	4'	H20-S16	24'&14'6"	14%	30°

1. Particular sections of road may be built to lesser standards where difficult terrain makes strict adherence to stated standards excessively costly.
2. Desirable design speed is not related to minimum standards shown.
3. 18' width should be considered as absolute minimum as any lesser width would be dangerous when heavy duty trucks meet.
4. Trucks 55 m.p.h.
5&6. Required for various street layouts.

OFF-ROAD TRUCKING WINTER OPERATION

BY: J.B. DENISON
TRUCK/AIR CO-ORDINATOR, PACIFIC WESTERN AIRLINES

The term "winter road" has been used since the days of the dog team and the ox-drawn sleighs in western Canada. It concerns the passage of freight over terrain that is passable by various types of vehicles when the ground is frozen and snow covered but impassable when the surface is not frozen.

The preparation of a "winter road" is commonly associated with the need to move large tonnages between widely separated points. The construction of the Alaska Highway and Canol Pipelines were outstanding examples of the need for this type of road. First, there was a great urgency, and secondly, no other means of transportation could cope entirely with the volume during the short water season nor were aircraft able to carry the huge machines they now transport.

The cat train was the vehicle of the "winter road" until the early 1960's. The tractor train was slow, cumbersome, expensive and difficult to marshall. The tractor and sleighs involved large capital outlays and the sleighs were useable for only a short time each winter. The freight to be transported, had to be handled several times as warehouses to consumer delivery is not possible.

As early as 1948, D & S Transport tried following a tractor train across the Great Slave Lake. It was an ordeal in twenty below zero weather with a blanket for a door window and a blowpot for cooking but the feasibility was established. This method was carried out with and without tractors until the Mackenzie Highway reached Yellowknife. This crossing varying from 150 - 200 miles and was dependent on ice which apart from thickness and pressure ridges presents few problems.

In the early 60's, the author was invited to try trucking to Discovery Mines Ltd., 50 miles north of Yellowknife. This brought an entirely new set of problems into the act. There was one job already completed though and that was a cat train road which had been used earlier but was as expensive as flying.

The first road which had no preliminaries completed was from Yellowknife to Tundra Mines Ltd. eighty miles inside the barren lands. A distance of 120 miles by air but nearly 215 miles by "winter road".

The plan of action initiated at that time still remains basic. It must be observed that we are dealing with the Precambrian shield where lakes abound in great numbers - there is no soil, only rock interspersed with muskeg, creeks, and rivers.

The first step is to fly a reconnaissance to establish the route. This involves picking places where the trucks can

leave the land and drive onto the ice, choosing the easiest route between the lakes, noting the grade of hills encountered and the amount of blasting required. Approaches by stream have to be picked carefully -- creeks that freeze to the bottom are useable but streams or rivers with flowing water erode the ice from beneath in unpredictable patterns.

The tentative route is picked and carefully marked on a topographical map. Construction takes place with a cat, truck, winches, drags, plows and blasting powder. When leaving the ice surface it may be necessary to traverse the shore for some distance to obtain proper slopes as hills or grades which require the trucks to be winched, defeat the purpose of the road. Boulders have to be cleared - within the tree-line trees must be removed and in some cases, rock blasted away.

Low spots in the road bed are filled with snow and dragged and packed. This is a critical phase as the snow must be compacted sufficiently to freeze from the bottom but not so solid as to delay the process overlong. The amount the snow is churned or worked in the process is important, as overworking the snow destroys the shape of the crystals and turns it to the consistency of fine sugar which resists compaction and freezing into a solid mass. This work is carried out in temperatures of -20°F or colder during the average winter.

The length of road that can be dragged in one operation in this construction phase is determined by the temperature. Where one mile might be dragged at -20°F, only one half mile would be dragged in one operation at -40°F in order to obtain proper compaction and freezing effect.

After a section of road is cleared and dragged, a truck is driven or pulled over the road and subsequent ruts filled in and dragged again until a workable surface is established. A heavy snowfall on such a road can cause problems as it seems to draw frost from the packed road in its freezing process and in such cases a vehicle may slide off the centre track and become stuck.

With the portage in workable condition, the ice is tested again on the lake and the snow bladed to the ice if the route is below the tree-line. Care must be taken to make sure that the route does not approach possible areas of current flow in the lakes such as river mouths or between islands. It is necessary also to watch for cracks in the ice which occur during the extreme weather. Places where two cracks join can be dangerous.

The large lakes also produce pressure ridges when the ice cracks and is forced into ridges as much as ten feet high. There is strong ice adjacent to these ridges and it requires much work in cutting through the piled up ice and bridging the cracks with timber. This pertains more frequently to lakes such

as Great Slave Lake and Great Bear Lake than the smaller lakes.

The roads on the ice are, of course, simpler to build as the Plow Truck takes the snow off the ice surface and a perfectly smooth road results. The wind drifts this road quite quickly and constant maintenance is required. This is not lost revenue though as the six wheel drive plow truck is also a tractor pulling up to 30 tons in a trailer. Where it is expedient, the road is gradually widened and this lessens the severity of the drifting.

The "winter road" construction in this manner eventually reaches the barren lands and here the technique is changed when building on ice. Beyond the tree-line the snow is compacted over the ice and the constant wind blows the loose snow from the track. There are, of course, places where drifts must be cut and these do present a drifting problem. The strength of the snow in the barren lands due to wind compaction approaches the consistency of cement.

Roads built in this manner provide rapid transit for the largest of tractor - trailer units and these travelling day and night move tremendous tonnages.

The movement of bunker oil due to its viscosity is a fuel one would expect to be impossible to transport in such extreme weather. It has been carried out, however, by heating the oil at the point of origin to 120°F and loading into insulated

tankers. It is sufficiently fluid to be pumped into storage after as much as 72 hours have elapsed at -40°F outside temperature.

The aforegoing description of the construction of "winter roads" would appear rather elementary but in addition to experience with varying ice and snow reactions to temperature, humidity and wind, there are other ancillary equipment and services required.

All trucks are self-contained and do not necessarily travel in convoy. There are normally two or three plow trucks working along the route. All trucks carry cooking and sleeping facilities and spare fuel - most are radio equipped.

A "Beaver", a vehicle equipped with wide floatation type tires and with winch - drag - tools - living quarters and radio, patrols the road and provides dragging duties. The wide low pressure tires do a minimum of damage to the road yet have extremely good traction and can move where other wheeled vehicles need a plow. A conventional one ton camper is also used on occasion for light rapid communication.

There are occasions where white-out conditions prevail during the day and all horizons and visibility become zero. In such circumstances the trucks "sit-out" the condition though they can usually travel at night.

The term "over-flow" is another foul problem to the

trucker. This is a condition where a heavy snowfall on thin ice in the fall of the year insulates the ice and slows the growth of ice depth. The weight of the snow depresses the ice and water spreads into the snow and eventually freezes into thin shell ice with a space between this and the true ice. This can affect large areas and pose serious problems of truck routing. There are also areas where the weight of the truck trailer depresses the ice and necessitates a new road around the area.

Due to the dispersal of weight on tandem units 18" of good ice is adequate. A common unit for this work is the 10 ton auto-car tractor powered by 250 HP Deisel units and pulling a standard trailer.

"Winter roads" make mining ventures possible in areas such as the Northwest Territories where railroads are uneconomical until huge deposits are proven and marketable in competition with similar minerals closer to existing surface transportation. The cost of winter roads vary with terrain but in the sparsely treed Precambrian shield, average about $100.00 per mile. The Federal Government "Tote-Road" assistance plan is of great help in making this form of transportation viable and has made possible the development of several good properties which would otherwise have laid dormant for years to come.

"Winter-roads" have proved to be economical and capable of moving large tonnages where no other surface means are

available and have the blessing of both Industry and Government.

YUKON ROADS

BY: K.J. BAKER
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It is significant to note that most of the roads in the Yukon were constructed to satisfy the need of the mining industry. You are all aware of the gold rush in the Dawson area and the subsequent springing up of gold camps on such creeks as Bonanza, Hunker and Dominion in the Klondike Valley. These camps in the beginning were served by foot and dog team trails and as time went on wagon roads were provided by the Government.

Roads of a low standard were also built in the Mayo area to serve the silver mines in that district and some roads existed around Whitehorse.

In the early 1940's, the construction of the Alaska Highway began and it will be remembered as a construction feat that was borne of the necessity of war. It consequently differed in purpose from all the other roads in the Yukon which were, and are, based on the resource industries. One wonders that if it weren't for the war if the Alaska Highway would ever have been built. During this period, the Haines Road, providing access to tide water, and the Canol Road, providing access to oil at Norman Wells, were also built, with all three roads totalling approximately 1,000 miles in the Yukon Territory. This is a significant length of highway built in a few short years and it forms the basis of the Territorial highway network.

Following the war, a highway link was built between Whitehorse and Mayo, and from Stewart Crossing on this road to the city of Dawson. This construction was completed in 1951 and ended the era of the steamboat. There was no further road construction in the Yukon until the roads to resources program commenced in 1959.

Control of the maintenance of the Alaska Highway and the Haines Road was turned over to the Canadian Government in 1946, and the Canadian army undertook the maintenance program. During the period 1946-1964, the army improved the surface by placing crushed gravel, replacing temporary bridging with modern structures, did a few miles of paving in the Whitehorse area and as a result, contributed to Canada what was known as the best gravel highway in the world. In 1964, the Canadian Government gave the role of maintenance to the Federal Department of Public Works. Forming part of this Cabinet decision was the statement that the Department of Public Works should enter into negotiations with the Yukon Government with the idea that the Alaska Highway maintenance would, at some time in the future, be turned over to the Yukon Government. It now appears that this handover will become effective in 1971.

Recognizing that there is a need for improving the highway, the Federal Department of Public Works has undertaken a reconstruction and paving program in the vicinity of highway communities. For example, 28 miles will have been completed in the Whitehorse area by 1971. It is hoped that this is the first step towards paving the entire length of the Alaska Highway.

As a special recognition of pavement cracking in cold climates, a soft asphalt cement is being used. Difficulties in rolling were experienced in the 1970 paving program leading to a rather imperfect riding surface when compared to more Southern paving jobs but as techniques improve, this problem will be overcome. From a layman's point of view, the pavement is a welcome respite from dust, mud, potholes, flying stones

and all the vehicle operating problems which are associated with gravel roads.

We would all like to see paved roads throughout the Yukon Territory but when one considers that paving only will cost approximately $80,000 per mile, then a large paving program in the Territory is a long way in the future.

To establish an interim solution, we were successful in 1969 in obtaining funds for the start on a dust control program. This consisted of 50 miles between Whitehorse and Carmacks and 104 miles on the road between Carmacks and Faro, the newest mining community in the Yukon. Calcium chloride was chosen as the dust pallitive. In 1970, a total of 208 miles were treated on the same route and the results over the summer were encouraging. The chemical was applied in flake form in two applications of 3/4# per sq. yd. One application was made in the May-June period and the second in the July-August period. Where we had a good crushed gravel gradation in the surfacing material, the surface was dust free and potholes did not develop to any great extent. Where the surface material lacked fines, potholes were more frequent but still not of such a size that the travelling public complained greatly. The elimination of dust was the main object from the safety point of view and the increased stability of the surface was a valuable side benefit. These two factors combined resulted in reduced travelling time between the town of Faro and Whitehorse and is an indication of the high quality surface that was obtained. In wet weather, however, the high percentage of fines which achieved a smooth surface in the

dry condition became very slippery. Fortunately, wet conditions are short lived and by prompt grading after rainfall, the desired smooth surface was again achieved. The cost of providing this form of dust control is $1,850.00/mile. This figure includes $130.00 per ton for calcium chloride or $1,200.00/mile and the balance is for surface preparation. It should be noted that the application of calcium chloride is carried out yearly. However, testing is being undertaken to determine if there is residual calcium chloride left in the road from one season to the next. If an appreciable amount is present then the present rate of 1½# per square yard can be reduced.

On more lightly travelled roads, we have been successful in obtaining a relatively dust free smooth summer travelling surface by ensuring that adequate amounts of binder are incorporated in the surface gravel. Although this leads to muddy conditions after prolonged rain, the semi-arid conditions prevalent throughout the Territory justify the use of this water bound type of surfacing.

In the winter months, we have few snow removal problems, again because of the low precipitation. The Watson Lake area has a greater snowfall than the balance of the Territory except at higher elevations such as the Dawson-Boundary and the Haines Roads. On these roads, winter storms dump considerable snow and accompanying winds cause drifting which at times forces road closures.

Over the years, we have replaced several ferry operations by the construction of bridges but there are still ferries in operation at Dawson City and on the Canol Road at the Pelly River. To facilitate the move-

ment of asbestos fiber from the Clinton Creek Mine, located near the Alaska border, over the freeze-up and break-up periods of the Yukon River at Dawson, a skyline is used which has a capacity of 10 tons and which can move 40 tons per hour. This skyline was built by the Cassiar Asbestos Corporation in 1966 under a cost sharing program with the Federal Government. Hopefully at some time in the not too distant future, a bridge will be constructed over the Yukon River at Dawson to fill in the last link of our trunk highway system and this will permit year-round uninterrupted flow of traffic from Whitehorse to the Alaska Boundary near Dawson City.

Several years ago, the Yukon Government made a change in the Motor Vehicle Ordinance permitting a five axle tractor trailer combination to gross 95,000 lbs. on certain Yukon roads, which is approximately 25% greater than the normal loads permitted in the provinces. This change is of great benefit to the mining industry since it enables them to ship mine products to rail head at Whitehorse at a reasonable cost. So far, the effect of high axle loadings on the trunk roads has not been too detrimental on the road structure and the direct effect on the road maintenance dollar is difficult to segregate from other costs.

On a typical trunk highway, the maintenance cost forecasted for 1971 will be approximately $2,700/mile and dust control on certain heavily travelled sections will be approximately $1,800/mile.

In addition to the milage of all types of public roads, that is 2,382 miles, tote trails are being built at the rate of several hundred miles per year by mining, logging companies and other resource developers. These roads are built under the Tote Trail Assistance Program in which the Government may pay up to 50% of the cost of construction. Expenditures on the part of the Government over the past few years are as follows:

1967 $100,000 for which 29 roads were built totalling 646 miles

1968 $ 99,000 for which 28 roads were built totalling 340 miles

1969 $ 80,000 for which 19 roads were built totalling 296 miles.

In 1957, commencing with the road which connects Mayo with the mining community of Elsa, a program of highway upgrading to trunk standards was begun. From a minimum program in 1957, work is now proceeding at the rate of 40-50 miles per year in order to keep pace with rising traffic volumes brought about by the development of mineral resources.

Since 1957, 566 miles of new highway have been built in the Yukon Territory under the resource roads program. This construction is proceeding at the rate of approximately 25 miles per year with emphasis at the moment on extending the Dempster Highway to Fort McPherson in the North West Territories. This road serves the oil industry by providing a supply route to the Peel Plateau.

As more and more development takes place in the Yukon, new roads to resources may be built in the near future which are not contemplated at this time because the resource industries can operate profitably only if adequate road facilities are available connecting to other

forms of transportation. Although for many years the travelling public accepted gravel roads, it is now apparent that with the influx of people who are familiar with asphalt or concrete roads an even greater demand is being expressed to improve existing road surfaces. This must be accepted and consequently, it may not be too far in the future when all the trunk roads in the Yukon will be paved just as they now are in the State of Alaska.

SOME CONSIDERATIONS FOR OFF ROAD VEHICLES IN NORTHERN CONDITIONS

BY: T.A. HARWOOD
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I INTRODUCTION

NORTHLAND VEHICLES TESTED BY THE DEFENCE RESEARCH BOARD BETWEEN 1960 AND 1969.

This paper might be interpreted to cover the wide field of Land Transport. However, since other papers have been submitted to this Conference on other phases of Land Transport on the Arctic and Sub-Arctic, it will be confined to a discussion of some of the various vehicles tested by the Defence Research Board during the past few years. Most of these vehicles are exotic to say the least and involve nearly if not all the design concepts which may come forward in the future and offered as a solution to "Northern Mobility".

The first step in this paper then would be to define some of the environmental factors around which a "Northland" vehicle has to be built and which, in many cases, the designers have so blithely disregarded.

II. GEOGRAPHY OF THE ARCTIC AND SUB-ARCTIC

To most people in Canada the Arctic is defined as the land which lies north of the treeline while the Sub-Arctic is considered to be a belt about 250 miles wide lying south of the treeline. This is sometimes called the Northern Coniferous Forest. The Treeline, being a function of climate, mainly temperature, tends to follow the 20°F mean annual isotherm, although this is not necessarily applicable along the Labrador coast and in the Northern Yukon. Permafrost, also usually considered as a purely arctic phenomenon. lies to the north of the 28°F isotherm. It is, therefore, found somewhat south of the treeline. To those of you who require further details I would refer you to the permafrost map of Canada (R.J. Brown, NRC, 1968).

1) Climate

The Arctic and Sub-Arctic, from Alaska to Greenland, varies widely in amount of precipitation, range of temperature, and type of terrain, and thus no general statement will suffice for the whole area. The only climatic condition common to most of the North is low temperature, both in the summer and the winter. In certain parts of the Sub-Arctic, such as the Lake Athabaska region and the greater part of the Yukon and Alaskan Territories, the daily minimum temperature may drop as low as -70°F. Even as far south as northern Ontario and north-western Quebec daily minimum temperatures of -60°F are experienced a few times every winter In the Arctic Islands or High Arctic a daily minimum of -60°F is also quite a common occurrence. During the summer, in sharp contrast, daily maximum temperatures in the Yukon and around Lake Athabaska may reach 95°F and at time 100°F whereas in the northern islands they seldom reach 60°F. It can thus be said that the extremes of temperature and range of temperature are much greater in the Sub-Arctic than in the High Arctic. (This is true also of the Soviet Union).

Winter precipitation varies even more widely across the northern part of the continent. The mean annual snowfall north in northwestern Quebec (Ungava) may reach as high as 200 inches and in most of eastern Baffin Island runs around

60 inches. Mean annual snowfall in Alaska also varies widely with as much as 200 inches south of the Alaska Range dropping to less than 30 inches on the northern coast and interior.

Maximum recorded depths, which are more indicative of conditions for which a vehicle has to be designed, show the same contrast. Throughout all of northwestern Canada from Hudson Bay to the Rockies, there is generally less than 30 inches on the ground at any time; whereas in northwestern Quebec and parts of Baffin Island the maximum depth of the snow on the ground may run as high as 80 inches. (In comparision, in the Soviet Union the maximum recorded depth in the Urals is 28 inches and elsewhere in the Union even less. (Snow cover, its Formation and Properties, Popular Science Series, Academy of Sciences USSR, Moscow 1945).)

2) Terrain.General Description

While it is impossible in a paper of this length to discuss at any length the physiography of the Arctic and Sub=Arctic in Canada and Alaska, it is again possible to distinguish between the main types of physiography which may affect vehicle design. These can be divided into four general groups and are:

(i) Mountainous terrain

(ii) The Precambrian Shield area - forested and treeless

(iii) The coastal plains - forested and treeless

(iv) The Arctic Islands

The mountainous areas of the northern part of the North America continent are located in the east along the northern Labrador coast and Baffin Island, northern Ellesmere Island, and in the west in southern Alaska, the Brooks Range and parts of the cordillera of the Yukon.

The Precambrian Shield, which underlies so much of Canada, is usually a rugged surface with relatively little relief, local relief seldom exceeding 600-800 feet. It is characterized by innumerable lakes and streams and many vegetation-filled lakes commonly called "muskegs". Since it has been scoured by the continental glacier, rocky knolls are extremely numerous. Owing to its ruggedness it is perhaps

the most difficult area on the continent to traverse, with or without trees.

The coastal plains, with which may be included the interior of Alaska, are in turn characterized mainly by flat wet (in summer) terrain, mainly muskeg, underlain by permafrost, forested and treeless, and are located around the coasts of Hudson Bay and James Bay, the Mackenzie Delta and the Alaskan coastal plain north of the Brooks Range. Where this type of terrain is underlain by permafrost, it may become almost impassable to men and vehicles during the thaw period.

The Arctic Islands, with the exception of some of the eastern islands, which are in places extremely mountainous, consist for the most part of limestones which have been weathered in places to a clay-like soil. Since these islands are all underlain by permafrost, trafficability conditions are difficult in summer though not as difficult as on the coastal plains. In the winter the rolling terrain is relatively easy to traverse by vehicles, though not perhaps as easy as the treeless regions of the coastal plains. However, the many deep gullies precludes point to point operation and numerous detours may be required.

Within these admittedly crude subdivisions two "facets" of the landscape dominate the problem of vehicle design. There are snow and muskeg. Both are low bearing strength materials but with other characteristics vastly different. Owing to their importance they will be discussed in a little more detail.

Left out of course is the macro relief of the Precambrian and the micro-macro relief of the patterned ground found in the permafrost areas. Such relief contributes to the violent pitching of any vehicle and thus to driver fatigue but does not materially affect the "go-ability" of a vehicle at low speeds. For this reason, since the subject of terrain and vehicle response should be the purpose of another paper it will not be discussed further

2) a) Snow conditions

Snow is an extremely complex material and the final condition of the snow cover is dependent on a large number of variables. These however, can be crudely divided into two main groupings:

(i) The temperature and humidity of the lowest layers of the atmosphere and therefore type and size of flakes which fall;

(ii) The subsequent temperature and wind conditions which cause metamorphism after the snowfall has taken place.

Let us now take a look at how these variations may affect surface "terrain" conditions.

Throughout the western Arctic and Sub-Arctic, precipitation usually takes place at very low temperatures and falls mainly as a crystal fog. The crystals are therefore small and cold. In the east, where a maritime climate prevails, snowfall is commonly associated with warm frontal disturbances and heavy falls of snow very often occur at relatively high temperatures, near 32°F. The flakes are therefore large and fragile, and a large amount of free moisture is usually associated with this type of snow.

Both types of snowfall when wind-driven on the barrens or above the treeline, metamorphose or change into hard wind-packed drifts which allow little penetration by a vehicle track.

South of the treeline the undisturbed snow, protected from the wind by the trees, displays entirely different characteristics. In the west, from the Hudson Bay coast westward, the snow remains loose and dry and settles down to fairly shallow snow cover with densities often as high as 0.2 grams per cc. The ground is normally frozen in the fall before the early snowfalls, and little sublimation, a process of metamorphism, takes place.

In the east, however, the warm, fluffy, low density snow tends to preserve the unfrozen nature of the ground. As a result a great deal of sublimation, due to the relatively steep temperature gradients which exist between the bottom and top of the snow, may take place, particularly in the lower six inches. This type of snow also tends to insulate itself against temperature changes, often maintaining an even temperature of about 22°-28°F approximately 6 inches below the sur-

face of the snow. There is therefore nearly always some free moisture in this type of snow cover, and as a result, processing or disturbing snow results in another type of metamorphism which can be most readily recognized as "age hardening". Thus the snow disturbed by a passing vehicle or vehicles tends to harden rapidly; and in cold weather, as little as four hours after passage, the snow may be firm enough to support vehicles and men. It may also have considerable structural strength and 12 to 24 hours later it may be "iron hard". In western and northwestern Canada and in central Alaska this type of metamorphism is less likely to occur owing to the lower temperatures and the smaller amount of free moisture in the snow.

The importance of all this to the vehicle designer is as follows:

(i) The deep soft snow associated with a maritime climate (eastern Canada) tends to insulate the ground but at the same time hardens after passage of vehicles, whereas shallow high-density snow, associated with a continental climate, tends to allow the sub-grade to freeze but at the same time does not metamorphose or harden so readily.

Thus the vehicle designer is left with three main types of snow cover to deal with. These are:

(i) Low-density, warn and deep snow, found in the eastern Sub-Arctic with an unfrozen sub-grade;

(ii) High-density, shallow snow, found in the western Sub-Arctic usually with a frozen sub-grade;

(iii) Wind-blown snow, found mainly in the barrens, and forming hard snow drifts.

These classifications are admittedly crude but serve their purpose. The Greenland ice-cap will not be considered here.

2) b) Muskeg

In the summer time in part of Arctic North America and throughout the Sub-Arctic muskeg is prevalent and has a consequent affect on vehicle design.

In North America the expression muskeg is in wide use, and is used to describe the living organic matter, the dead material below the living matter (peat) and the underlying mineral soils. Elsewhere muskeg is known by a variety of names, such as peat bogs, wetlands, etc. For the above definition the organic material must be at least 6" thick. Visually muskeg can be described thus "the living vegetation covering the terrain composed of mosses, sedges and/or grasses, with or without shrubs or low (not more than 12 ft) tree cover. Underneath this is a mixture of fragmented organic material derived from past vegetation but now chemically changes or partly fossilized. This material is commonly known as peat or muck". This sub-surface peat is usually highly compressible, very high in water content, (up to 1000%) and usually is of very low bearing capacity.

Other features are inplicit in an understanding of this terrain. Conditions in the peat are aerobic, usually highly acidic (humic acid) and at times partly colloidal.

Under these definitions muskeg can be very widespread. In Canada alone there are 500,000 square miles of this phenomena most of which is in the Sub-Arctic, and it is wide spread in Alaska. In the USSR the extent of the exploitable 'peatlands' are claimed to be over 600,000 square miles which using the above definition would probably amount to more than 1.4 million square miles of muskeg. To the west more than 30% of Finland is muskeg covered.

Since muskegs or 'peatlands' very seriously inhibit trafficability and thus commercial and military operations the tendency is to think them impassible. Research, has shown that this is not necessarily so, however, certain characteristics are bound to affect the ability of any vehicle to traverse some features more

than others, and until muskeg, in 1952, was classified there was not real basis on which to conduct studies of vehicle performance in muskeg. A system has now been devised which includes nine major cover types and sixteen peat types and an indefinite combination of these. From these studies an understanding in vehicle mobility across muskeg has been obtained.

Simply stated, the living cover provides a 'mat', that is the living flexible roots, stems and branches tend to interlock thus spreading and supporting men and vehicles through their own tensile strength. A measurement of the strength of this 'mat' based on the muskeg classification system mentioned above gives an indication of trafficability. Considerable research has been done in this area both by the Defence Research Board, Universities and Calgary based Companies. The results are well known. Reasonably good vehicles have been built to cross muskeg and a large number of exotic vehicles have been tested.

III THE PROBLEM OF DESIGNING A "NORTHLAND" VEHICLE

It can be seen from the above that the design of a "Northland" vehicle to fit all conditions of snow, terrain (muskeg) and climate is a complex engineering problem, for there are many objectives, all different but all related.

The operational problem is, of course, one of economic maintenance and mobility and would be even more simply stated by a question "will one or all of these vehicles get through cheaply?" and this must be answered no matter whether the vehicle is operating in snow on a confined trail, say in the bush, across muskeg, or on the open barrens where it may pick and choose its way and under any climatic condition.

But to assess the mobility of vehicles is extremely difficult since the assessor must be certain of the similarity of test conditions such as the snow or the terrain, and test equipment; while the latter may be kept constant the former may vary widely. Thus the mechanical properties of the medium must be known. In the case of snow this has only been attempted in Canada and the United States in the years between 1946 - 1956 with not too much success. However, a great deal of testing has been done in muskeg, which may well be the more difficult medium, and here we can speak with some surety.

In addition to having the design for such a complex medium as snow, or muskeg, the designer is also faced with the possibility of metallurgical and rubber failure, particularly in the suspension due to the very low temperatures which may be encountered.

It now becomes obvious, particularly for anyone who has much to do with vehicle design, that there probably can be no such thing as a practical all-purpose vehicle and all-terrain vehicle, and it is equally obvious that if such a vehicle could be designed, it would have less desirable characteristics in the terms of load-capacity, range and mobility than a vehicle designed, take for example in the mid 1950's, for any one condition or a limited set of conditions. Comparision of the Tucker Snocat designed specifically for the soft and deep snow encountered in

High Sierras of California and Oregon with the military Weasel (M29), and a five-axle semi-trailer demonstrates this fundamental fact. Similar comparision would be made for summer terrain conditions.

To all these complications in vehicle design, brought about by having to allow for climate, terrain and snow conditions, are added the very necessary load carrying characteristics, which are often in contradicition to what is required for good mobility.

From all this it can be seen that the designer of an optimum "Northland" is faced with an almost insuperable problem. As a result, the solutions which have come out of Canada and the U.S. in the past few years are numerous and have varied very widely in their approach.

IV SOME SOLUTIONS

1) Self-Propelled Oversnow and Muskeg Vehicles

An astonishing number of self-propelled vehicles have been built in answer to the incessant demand from civil and military organizations for a "Northland" vehicle. Many have been designed for specific conditions and many have been put forward as universal vehicles for both winter and summer operations in the Arctic and Sub-Arctic.

These vehicles can be classified into eight groups according to their running gear, and are:

Archimedian screw vehicles

Propeller ski vehicles

Half-tracked vehicles

Full-tracked vehicles

Wheeled vehicles

Air roll vehicles

Air supported vehicles

Articulated tracked vehicles

All the above, except air support vehicles, which deserve separate and more detailed treatment, will be discussed individually (Annex A).

1) a) Archimedian screw vehicles

There have been numerous attempts to produce machines which would be propelled through the snow by Archimedian screws. A vehicle propelled by a cylindical screw dates back to 1920 and during World War II the Germans tested a vehicle in snow. The modern version of this vehicle was developed by the Chrysler Corporation for use in "wet" lands. There is no analytical solution which defines the pull-slip curves for the screw in the same manner as it does for the track. However, the action of the screw at low speed can be compared to the action of a track and particularly to the Tucker Snow-Cat (Bekker 1963a). In each case the soil may be assumed to be trapped by the screw blades and grousers and moved long-

itudinally with reference to the supporting surface. (The pontoon or the Sno-Cat ski). No rigorous confirmation has been made of this theory under a number of environmental conditions and so far no screw vehicle has proved practical.

1) b) Propeller ski vehicle

The ski-borne air-propeller-driven machine, of which many types have been produced both in this continent and in the Soviet Union, has numerous drawbacks which keep its application to either extremely light machines or to areas where snow conditions and level ground limit the maximum thrust-to-weight ratio to around 0.2. It has been found that for all-round service, together with the ability to master reasonable grades, such machines would require the installation of approximately 350 h.p. per ton. This is approximately the requirement for the present-day 5-passenger helicopter. Thus from the aspect of fuel consumption and payload to gross weight, this type of vehicle does not appear to be practical

1) c) Half-tracked vehicles

The combination of the ski and track in small machines as the four pontoon Tucker Sno-Cat, the Frandie Snoshu (centered ski) and the ski-doo has been successful in deep snow and may be thought of as an attempt to ultilize the ski without the high power-to-weight ratio necessary for air-screw ski propulsion. Another attempt along the same lines has been the light load-carrying sled toboggan, propelled by a small floating rack unit mounted usually between the sliding surfaces and carrying about 50% of the gross load. The success of these machines depends entirely on keeping on the top of the snow cover so that motion resistance and tractive requirements are kept to a minimum. The extremely low unit ground pressure required to operate these vehicles over snow make their development into a true load-carrying machine appear unpromising.

On the other hand there are several machines which use the ski in combination with a true load-carrying track, an example being the skimobile and Bombardier snomobile. Here only enough weight is carried on the skis to provide steering so that in the final analysis these vehicles are essentially tracked vehicles with ski

steering substituted for track (locked tracks) steering. This is in some ways a desirable feature for it eliminates the "digging in" which occures in soft snow when track steering is used. The trend, however, is away from these vehicles, owing to the mobility limitation imposed by the ski or in the summer, a wheel, on rough ground.

1) d) Fully tracked vehicles

The most successful class of self-propelled vehicles are the full-track laying type. A number of the vehicles of this type are obtainable commercially and in wide use.

The original Canadian Army "Penguin" which was the forerunner of these vehicles used a type of track or a variation, originally developed in Canada at least, by Bombardier. As a group these vehicles do not have high mobility in snow encountered in the trees, and over 30" in depth, undisturbed with a low density, and with a 6" sublimation layer. Nonetheless they come, for economic reasons,closer to a general purpose vehicle than most other types.

There have been several efforts to improve track design and in the 1950's a great deal of development was undertaken around small fully-tracked vehicles using the "spaced-link" track; that is a track with large spaces between the grousers and the links. This might well be called the "open hole" track. The "Groundhog" and"Beetle" were such vehicles and an effort was made to raise the belly and reduce its transverse dimension to such an extent that they might be called "bellyless" vehicles. These fully-tracked vehicles, in comparison to the ones earlier mentioned, have shown superior drawbar performance and this is thought to be due mainly to the markedly reduced motion (rolling) resistence, i.e. the reduction of the bow wave seen in front of any tracked vehicle. It is quite possible that the basically different mode of shear in the snow or muskeg developed by this track in comparision to conventional tracks also plays an important part. Indications were that the improvement demonstrated could only be practically achieved in small machines (below 10,000 lbs. gross). That this was pro-

bably so is indicated by the fact that development was dropped by the U.S. Army.

1) e) Wheeled vehicles

The use of ordinary wheeled vehicles in the Sub-Arctic and Arctic is, of course, limited to cleared roads, but specialized wheeled vehicles with large-diameter low-pressure tires have been tried with some degree of success.

It is interesting to note that one of the original vehicles of this type, the Poulter-Byrd Snowmobile, was used in the Antarctic as early as 1939 by Admiral Richard Byrd. This vehicle had wheels 10 ft. in diameter and two 150-h.p. engines, and weighed approximately 17,500 lbs.

One of these vehicles the "Gulf Buggy", tested by the Defence Research Board in the 50's appeared to have the high mobility both in fresh and undisturbed snow on rough but otherwise unprepared trails. The vehicle was, however, extremely large and cumbersome with a high silhouette, which is in itself unacceptable from a military point of view. There appeared to be little chance of reducing its size without a loss in overall mobility. The possibility of increasing the load carrying capacity, however, seemed to be better.

The Letourneau Snow Buggy, from which developed the Letourneau "Snow Train", had the same diameter wheels as the Gulf Buggy but were 45% wider. This vehicle was successfully tested on the Greenland Ice-cap, and the later version "Snow Train" was quite successful on the Arctic coastal plains of Alaska and north-western Canada. A steel wheeled vehicle, similar to the "Gulf Buggy", called the "Swamp Skipper" has also been tested. In the muskeg around Fort Churchill it proved to be the only vehicle capable of crossing certain areas. The steel wheels, however, are difficult to maintain, and for this reason has never been exploited.

The Rolligon so far has not proved to be a successful over-snow vehicle in the undisturbed snow found within the northern coniferous forest. The Rolligon is a standard military pattern vehicle (U.S.) modified in such a way that the front wheels are replaced by a large balloon bag filled to 3 psi. The two rear wheels

are similarly modified. The drives and steering were, however, quite complicated. This vehicle operates on the concept that the balloons, deflated to less than 3 psi, can assume the shape of an ellipse and the shape of the lower side of the part of the ellipse can in effect be considered to have the properties, so far as the soil is concerned, of a very large-diameter (15-20 ft.) tire. By this means nominal ground pressure is further reduced and rolling (motion) resistance is lowered. This vehicle concept was dropped by the U.S. Army (Transportation Corps) but strangely the development of the Rolligon Tire led in its turn to the "seal drum" now in use in Vietnam and Northern Alaska.

1) f) Articulated vehicles

One of the pecularities of all wheeled and tracked vehicles is that maximum drawbar pull is only sustained at some percentage of slip between the track and the soil, usually about 17-22% (Fig. 1). After reaching this point the drawbar pull or tractive capability fade off. Thus when a vehicle is operating with both tracks developing maximum pull at optimum slip, anything which moves either one one of the tracks down on either side of the pull slip curve tends to immobolize the vehicle. (Fig. 1).

This usually means that just when the vehicle is on the verge of "bogging down" the driver usually, attempts to steer the vehicle to harder ground leading quickly to disaster. Again in cohesive soils the pull-slip curve is far more pronounced than in non-cohesive soils, with the result immobility occurs more frequently. Thus no matter what the vehicle, so long as it is differently steered, the ultimate in continuous draw-bar pull is seldom achieved. The solution of course is to use a broken-back vehicle (articulated) designed in such a way that all four tracks are in contact with the soil and all tracks run at the same speed (or slip). This means that the front part of the vehicle with respect to the rear part must be free to move with three degrees of freedom (roll, pitch and steer).

The commonest, concept of an articulated vehicle is of two vehicles of miror image coupled together by a universal joint,driven by one motor through an

articulated shaft. This has certain disadvantages, the main one being the splitting of the vehicle and the complicated drives. To offset this disadvantage various manufacturers have come up with variations of the concept. One such concept allows the track to be coupled to a rigid frame, much like bogies in a railroad car, the other like a fifth wheel truck trailer but with the trailer wheels driven and having two degrees of freedom. Both types of vehicles are now commonly used in the North.

However, if the ultimate in off road mobility is in the true articulated vehicle why then is it not used more often? The answer is that besides the disadvantages of the split vehicle there is the added expense, for one has to literally buy two vehicles to obtain say a 10% increase in mobility and while the armed forces may do this private enterprise is not likely too. Thus the compromise mentioned above. Nonetheless the ultimate in mobility for Northern operations lies, in the author's opinion, in the articulated vehicle or some modification of this concept.

1) g) Air roll vehicles

The air roll type of vehicle rides on wide pneumatic tires linked together by a continuous chain. On hard ground the track wheels roll between the grou and the roller support with an overdrive of 2.1, i.e. the ground speed of the vehicl is twice the track chain speed. In soft ground the rollers stall and act as large cylindrical track grousers while the wheels now slide on the roller support. This as can be seen is a modification of the Tucker "Sno Cat" principle. An analysis of this concept shows that the grouser action of the Lockheed-Forsyth Vehicle operating is soft soil is partially similar.

Necessarily these vehicles have a highly complicated and vulnerable track system, and for this reason their commercial applications have been limited.

2) Non Self Propelled Vehicles

Winter logging operations in Sub-Arctic Canada were, up to a few years ago, almost entirely carried out by sled trains hauled by tractors or trucks on

prepared roads, The trend now by operators is towards a wholly truck haulage operation. However, due to the need for off-road communication, the Canadian Army made considerable efforts to develop sleds suitable to be towed behind tracked vehicles.

Perhaps the most highly developed sleds as regards suspension and frames, certainly in North America, were Canadian Army "Northland" sleds. These were spring-mounted runners and of aluminum construction. The aim of this type of runner is to obtain better conformance to irregularities in the snow-covered terrain. This it has been found, simplifies loading and lashing of loads and when used as personnel carriers, reduces personnel fatigue. These sleds were developed for 2-ton and 4-ton loads. A sled or a ski configured vehicle would on the surface appear to be relatively simple vehicle to design. However, besides the complexity of the snow surfaces which has been mentioned earlier, there are other considerations which further complicate the problem. These considerations all revolve around the frictional properties of snow against a sliding surface. As in all sliding surfaces involved is starting friction and sliding friction, and as will be seen in snow these parameters are complicated by many factors. The following is a result of a great deal of work done in Sweden for the design of sleds in the forest industry and in the United States for the design of skis for aircraft.

Starting Friction

i) The coefficient of friction varies inversely with the snow grain size; the larger the grain the lower the coefficient of friction;

ii) The coefficient of friction varies directly as the temperature of the snow;

iii) The coefficient of friction varies directly with the time the vehicle is stopped.

Sliding Friction

i) The coefficient of friction varies directly with the heat cap-

acity and conductivity of the runners, i.e. a steel-shod wooden runner slides more easily than a steel-shod aluminum runner.

ii) The coefficient of friction improves as the rigidity of the runner is increased.

iii) The coefficient of friction varies inversely as the smoothness of the runner, i.e. a rough surface slides easier than a smooth one.

iv) The coefficient of friction varies inversely to grain size.

v) The coefficient of friction varies inversely to the length of the runner but directly as the area of the runner.

vi) Perhaps more important the coefficient of sliding friction appears to vary almost logarithmically inversely to load, for a tripled load the drawbar pull need only to be doubled.

From all the above it can be seen that the problem of design, the selection of the optimum size and shape and of suitable materials for a sled or runner, is quite as complex as that of designing an over-snow vehicle. It should also be noted that, assuming there is a requirement for a towed sled, the designer is also faced with the task of assessing the optimum power (drawbar pull) of the tractor against the load to be pulled. Statement vi) above shows how difficult this may be when he is faced with a set of rigid characteristics and specifications.

Quite aside from the design problem however, the major drawback to sleds is, of course that they cannot be used except on ice and snow.

2) b) Tracked Trailers

Experience with tracked trailers for summer use such as the "Athey" Wagon, has generally not been successful, and generally constitute a minor improvement over the "Stone Boat" on permafrost surfaces. In this case damage to the surface has not been considered.

V GENERAL COMMENTS

The following comments can be made on the limitations of vehicles in the Arctic as a result of experience.

1) Mobility of Vehicles in the Arctic and Sub-Arctic. Limitations.

Within the Sub-Arctic, so far as can be ascertained from Canadian and Soviet experience, mobility is limited not so much by the depth of low density and dry snow but by the strength of the subgrade beneath the snow. If the ground is unfrozen the mobility of any tracked vehicle is drastically limited, particularly if the early winter snowfalls have been preceded by late autumn rains. This is due to the fact that the approaches to lakes, muskegs, swampy areas, etc., remain unfrozen and the vehicle breaks through the snow cover, which has little or no bearing strength, and immediately churns up the moisture-laden ground. This combination of snow, water, mud and organic matter can quickly halt even the best machine.

In the summertime, within the permafrost zone, similar difficulties are encountered, as the permafrost tends to seal off the thawed surface layers of soil so effectively that no subsoil drainage takes place. As a result, the surface soils are usually super-saturated and when disturbed quickly become a morass.

There is yet another limitation to mobility which may occur in the spring or fall, in areas where heavy wet snowfalls occur. Wet snow with a high moisture content tends to pack readily, as any boy who has made snowballs knows. When such snow packs around the suspension of a tracked vehicle it may stress the tracks seriously, often to the breaking point. This, together with the loss of what little shear strength there is in the snow, tends to immobilize the vehicle quickly.

Besides the difficulties caused by an unfrozen subgrade permafrost, terrain and muskeg, there is also a mechanical limitation to the mobility of fully tracked vehicles. In deep snow, or on unfrozen ground such as the active layer of the permafrost in summer, and even on hard packed snow, when track (skid) steering is used, the vehicle tends to skid around on one track and dig itself down very rapidly.

This of course, is the reason why vehicles of all types bog down or lose mobility when operated by a poor driver or on trails with tight turns (see p. 15). Several alternatives have been proposed to overcome the difficulty caused by this type of steering. One of these is the method employed by the Tucker "Sno-Cat" in which both the front and rear pontoons steer. Another development is the articulation of the vehicle chassis itself; that is the use of two fully-tracked vehicles, one steering the other. The results of this solution are extremely encouraging. As mentioned the limiting factor appears to be economics.

Finally there is the human problem of bad driving, and therefore poor mobility. The cause of bad driving may be cold, low visibility, darkness and poor riding characteristics of the vehicle. All these tend to increase driver stress and fatigue. The driver thus loses his ability to maintain the optimum power requirements necessary to obtain the best forward speed and slipping or stalling occurs. This in turn drastically reduces mobility and is difficult to overcome, but in my opinion has been overcome by the development of FMC M.113. In this case the M.113 has a high horse power engine with a torque sensitive "gear shifter" (torque converter). Thus when the vehicle is operating in "low range" the torque converter "feels" the change in terrain conditions (shear etc.) before the driver. It therefore shifts down before the vehicle comes to a stop and loses momentum. In other words it attempts to keep the vehicle up on the pull-slip curve. If this is correct it would therefore appear that the limitation to the mobility of many track vehicles without torque converters lies in the drivers insensitivity to terrain changes, rather than in the capability of the vehicle itself.

2) Observations

It is now possible to summarize and to make a few observations which must be borne in mind when considering a design of any so-called "Northland" vehicle. These are that:

i) The Arctic and Sub-Arctic vary as widely in climate, terrain and precipitation as any other area of similar size (approxi-

mately 2.5 million square miles) in the more temperate latitudes;

ii) The only climatic factors generally common to the Arctic and Sub-Arctic are low winter temperatures and the wide range of temperatures.

iii) The only physiographic feature found in the Arctic and not also found in temperate latitudes is permafrost.

iv) There have been at least eight different approaches to the design of an oversnow or "Northland" vehicle, none of which has proved in itself entirely satisfactory. These have been:

a) The Archimedian screw vehicle

b) The propeller ski vehicle

c) The half-tracked vehicle

d) The full-tracked vehicle

e) The wheeled vehicle

f) The Air roll vehicle

g) The articulated vehicle

h) The air supported vehicle

v) Mobility in winter in the eastern Sub-Arctic in coniferous forest is affected as much by the sub-grade as by the snow.

vi) Mobility in summer is drastically affected by the subgrade when permafrost is present.

vii) Mobility in summer and winter can be seriously affected where unfrozen muskeg is present.

viii) Starting friction and sliding friction on snow can be affected by a very large number of factors.

VI CONCLUSIONS

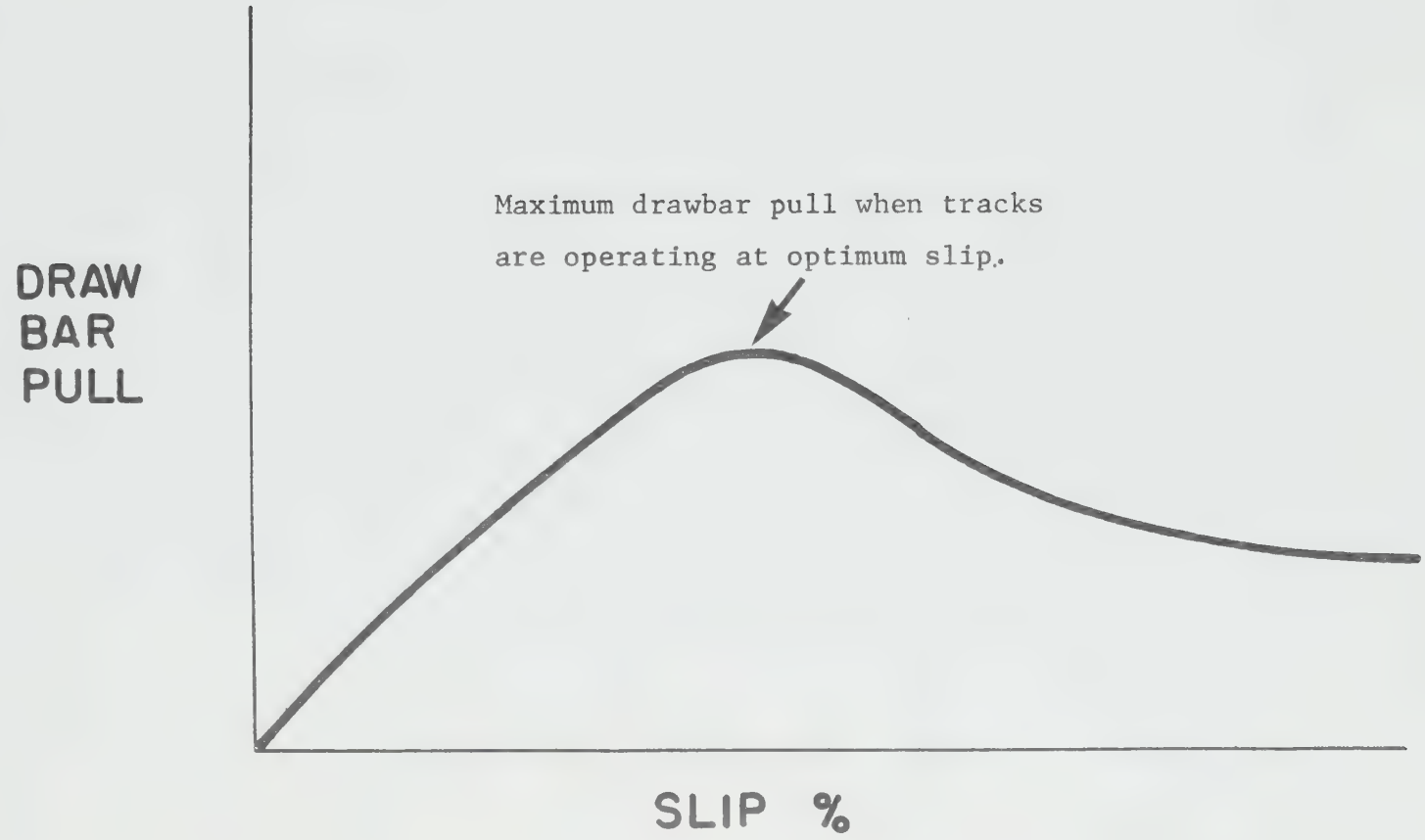
From all this it may be concluded that:

i) Owing to the wide variations in climate, terrain, etc., it is unlikely that a universal "Northland" vehicle, using any of the eight concepts above, can be developed which will have good mobility in all snow and soil conditions and for both summer and winter,

ii) It appears that a vehicle might be developed for use in the greater part of the Arctic and Sub-Arctic in winter, owing to certain similarities of snow conditions and terrain. The area involved would probably be everywhere north of the treeline except in the mountainous areas of Baffin Island, Greenland and Alaska, and within the treeline throughout northern Ontario to the Rocky Mountains and Central Alaska. The commercial vehicles presently available appear now to approach this desideratium.

iii) The factors involved in designing an even better "Northland" vehicle which is cheap and economic are many and complex. However a combination of tracked vehicles to make up an articulated vehicle may well develop. It is certain however that the only concept which will give nearly 100% mobility will be an articulated vehicle.

This paper has attempted in a very broad and general way to discuss the problems and factors involved in transportation and in design of suitable vehicles for use in the Arctic and Sub-Arctic. The subject is always controversial and it is difficult to do any more than indicate what the trends or solutions may be.



Generalized Pull Slip Curve

AIR CUSHION VEHICLES
Some Considerations for Northern Operation

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The Air Cushion Vehicle, from now on to be called the ACV, is a vehicle which does not depend on a soil-vehicle interaction to achieve its mobility. It is for this reason that it has not been described in detail in the paper on "Northern Vehicles", but has been included as a separate item (Annex "A") to that paper.

The ACV, it must be realized is not an aircraft, although due to weight considerations a great deal of air industry technology has gone into the design of the vehicle.

The ACV depends entirely on the air cushion for levitation and for fundamental reasons (the "ground effect") this air cushion is usually about four inches in depth. Thus to overcome irregularities in terrain air cushion vehicles commonly use flexible skirts which while they do not affect the 'hover-height' do allow obstacle clearance to be increased to 3'6" in one generation of vehicle and to as much as 8' in some larger vehicles in forthcoming generations. In this case, when an ACV operates at sea, a wave is considered to be an obstacle.

Since the vehicle operates onan air cushion it can be thought of as being frictionless, and while this drastically reduces the power required for movement, on level surfaces, it has serious disadvantages when the vehicle is climbing hills or crossing side slopes due to its extremely low drawbar pull-weight ratios. However, the frictionless operating surface also allows for high speed, on level ground.

The ACV cushion is usually maintained at 0.3 psi (note that certain smaller oversnow vehicles are quoted as operating at this nominal ground pressure) by blowing air through a large fan into the skirt area, which is usually divided into plenum chambers. Again the formulas to achieve the cushion, forward thrust and optimum weight are complex, however, generally speaking two thirds of the power goes to the cushion and one third to the thrust devices Thus while there are advantages in maintaining the vehicle on a frictionless surface it must be realized that there is a very large power penalty to pay. This penalty has consequences which are not often considered or not usually clearly explained. The result, however, is that the range of the vehicle, contrary to a normal vehicle,increases with speed i.e. there is no economical cruising speed in the real sense of the word. This means that when the vehicle is operating in an environment where obstacles are frequent and speed severely reduced, range too is equally severely reduced.

Since the vehicles so far produced have no contact with the soil their turning or manoeuvring capabilities are solely a function of aerodynamics, that is by interaction of a foil (rudder) surface acting on the air. This results in an extremely wide turning circle and for the same reasons cross winds, approaching the vehicle speed, cause excessive crabbing and a consequent reduction in speed.

The only solution here appears to be for the design of a keel like device, probably a highly flexible track, which will maintain direction by forces exerted on the vehicle through a soil-vehicle interaction. This will be discussed further. In some respects this has been achieved in certain sea-going vehicles through the employemnt of solid side walls and rudders.

From all the above it can be seen that in exchange for the outstanding virtue of very low ground pressure and a practically frictionless surface on which to operate, the ACV has many vices. The most serious of these being:

1) lack of manoeuvreability
2) lack of hill climbing ability
3) lack of lateral stability on cross slopes
4) lack of manoeuvreability in high winds
5) relatively low obstacle clearance

It would appear therefore that for a land-going vehicle these undesirable features must be designed out.

Let us now look at some of the specific reasons why in a Northern Canadian environment many of the ACVs presently available must be modified in such a way that they must be able to parallel, operationally, the more conventional vehicles.

It has generally been stated that an ACV could operate, summer and winter, on cheaply constructed "Hoverways". This is dubious and for the following reasons. In view of the limitations listed earlier the "Hoverway" would have to be:

1) wide
2) without cross slope
3) all vegetation cleared (so as to maintain the cushion)
4) no slope to exceed 12% (present limitation)
5) very wide corners

To achieve this, the so-called "Hoverway" would require at least twice the effort that is now required to slash out a conventional winter road.

Put more simply the "way" would have to be tailored very considerably to the vehicle and which is not now the case for winter roads.

Furthermore, the open tundra is not,as most people think,a flat vast plain, but even on the North Slope of Alaska and in the MacKenzie Delta, a region intersected with moderately deep ravines and high (four feet) polygon circles. Here again without considerable modification of the terrain ACV operation is impractical.

Much the same problem exists when the vehicle is used in operation over ice. Here once again the ACV has some virtues which, as in the land operation, are offset by its vices. It has one very good advantage in that it is unique among surface vehicles in that it has the ability to disregard the bearing strength of the ice and its combination with open water. It can thus operate right through the freeze-up and break-up or amongst open leads in the winter. However, this advantage is offset by the 'roughness' (obstacle height spectrum) and the slipperiness of sea ice.

Let us now look at the nature of sea ice in a little more detail. Sea ice is made up of so-called "fast" ice, and moving pack ice. Shore "fast" ice can be quite smooth and in certain areas provides a perfect "Hoverway". However, depending on conditions at the freeze-up, such as tides, on-shore winds etc. it can be quite rough. It is therefore not possible to assume in any given year that any one area will be smooth, and even if a course can be laid across such a smooth area, major movement of the sheet as a whole may cause ridging of such complexity that the track would have to be resurveyed.

Pack ice, of course, is quite another matter since the whole mass is in movement, periodically forming ridges and leads as weather systems move across an area. Thus a track laid out across this type of ice may only last a few days.

With all this in consideration any ACV designed for operating over the ice must take into account the maximum obstacle height and for manoeuvreability,the frequency and pattern of the ridges.

The question here arises as to exactly what one must design for. At the moment only guesses can be made, however, the airborne profilometer has shown itself capable of measuring surfaces to a few inches and thus in time will provide exact information.

The best educated guess at the moment is that to move freely in most areas a clearance capability of 8' will be required, but as to manoeuvreability, which is dependent on ridge patterns, not even an educated guess can be made.

Much of the same limitations apply to river ice.

We should at this point outline some of the technical and operational problems of an ACV in a Canadian Northern environment. Quite obviously the design engineer must build into the machine the capability of operating in extremes of temperature and any associated weather. Such design requirements are built into any military vehicle accepted for standardization in the ABCA countries. These specifications are readily available,and in truth the climatic specification may be <u>too</u> rigorous for the environment envisaged here and could be relaxed.

However, the technical problems which are basically dependent on the climatic factors are:

1) Power plants - a proven turbine or reciprocating engine and in the case of the reciprocating engine special priming and oil dilution is necessary.
2) Hydraulic systems - to be up to ABCA standards for aircraft.
3) Electrical systems - the use of sophisticated (NiCad) batteries must be considered together with high charge rate generators.
4) Skirts - skirt systems must be up to ABCA standards for rubbers. A separate area which will require research is in the durability of such rubbers at low temperatures.
5) Cabin heating - adequate cabin heating is required for crew confort and must be from systems independent of the power plant.
6) Navigation - for operation clear of land, i.e. on the ice, simple inertial systems must be employed. Elsewhere standard marine radars with low precision gyros can be synthesized into a reliable system from presently available technology.

Finally let us now look at what is really required for an ACV which will operate on:

i) a Hoverway in the bush
ii) over shore-fast ice
iii) over pack ice
iv) on rivers

It would appear the following criteria must be designed into the vehicle. These criteria are:

a) manoeuvreability

b) small circle turning

c) quick deceleration

d) cross slope stability

In the author's opinion all the above can only be achieved by incorporating some device by which a soil-vehicle interaction can take place which will supply sufficient forces external to the vehicle so that it can achieve the capabilities mentioned.

If this can be done the next obvious step is to further refine such a device so that it will assist the vehicle on steep slopes. The device should also be retractable so as to obtain suitable obstacle clearance and to do this obstacle heights must be defined in such a way that it can be incorporated into the design.

What all this attempts to say is quite simple. The vehicle, so far as Northern Canada is concerned must be designed around the terrain features, and since this vehicle must for weight considerations, incorporate air industry features, it will prove to be a difficult design problem. The question is why will it be so difficult? The answer of course lies in the fact that the bulk of the off-road vehicles now in use are so overdesigned (at low speeds) that the terrain seldom affects the vehicle. That is, the vehicle forces the terrain to conform to it. A caterpillar tractor is a good example of this. The ACV for the reasons earlier described cannot do this and therefore must be designed to conform to the terrain rather than the other way around.

Thus one is left with the inescapable conclusion that if the ACVs virtues are such that they become overriding considerations, i.e. low ground pressure, the ability of operating in thin ice, over water and an ability to operate through the break-up, the vehicles must be built in such a way that they conform to limitations imposed by the terrain and by so doing overcome them.

Therefore it would appear the first step is to achieve manoeuvre-ability. This does not mean to say that it must become an air cushion assisted tracked vehicle which fundamentaly depends on soil-vehicle interaction, but a true air cushioned vehicle (insofar that its mobility would come from the air cushion coupled to the thrust from the air screw) using the soil-vehicle interaction only to derive those additional forces, which are required for manoeuvre-ability, hill climbing and braking.

By such a concept, together with proper obstacle clearance, the vehicle could be made, in some degree, to conform to the terrain thus gaining some or all of the advantages of the true ACV with some of the characteristics of a wheeled or tracked vehicle.

None or all of the above is intended to disparage the present vehicles, for they are eminently suitable for operation in shallow water and areas without harbours, but it is hoped that any future design of a vehicle built for a land operation will incorporate some of the above concepts.

OFF-ROAD VEHICLES-ENVIRONMENTAL CONSIDERATIONS

BY: M. CARPENTIER
VICE PRESIDENT, BOMBARDIER LTD.

From previous speakers we have heard something of the frustrations experienced by those who inhabit the north; but we who live below the sixtieth parallel also have our frustrations in attempting to understand the North. In short, there are frustrations everywhere and in that respect the North is very much part of Canada.

It is a cliché to say that Canada's future lies in the North but I prefer to think that there lies our present. Now as I understand this Conference, everyone here knows that the coming of industry may be a threat to the fragile balance of nature and that transportation, so essential to progress, is at the same time one of the more serious threats. We must therefore balance the benefit and the cost.

Benefits from the discovery of oil will profit North America as a whole and, as the United States has a pressing need for oil and natural gas, they will doubtless buy whatever we can sell at a competitive price, thus benefitting the Canadian economy in particular. The big impact of this will be felt in Western and Northern Canada but I hope that we Easterners can hope to share too. Those then are the profits - what of the cost?

Pollution is a cost and, if we had a clear understanding of the effects, no doubt we could put a figure on it. What is the cost of destroying an environment without which we might endanger the existence of wildlife and perhaps of man himself? If we would avoid pollution we must be prepared to meet that cost. Should we pay now, or later? If we would take steps now to avoid future pollution, undoubtedly we must pay now; if we don't, assuredly we will pay later, or more likely the next generation will. The choice seems a clear one but in fact it is not as simple as it seems and there are other influences to be considered.

Even if we pay now we cannot reduce the risk to zero; the only way to ensure total protection would be to accept total disengagement. No matter what precautions are taken there will always remain some degree of risk, be it of pollution by oil spill, of soil damage, or of destruction of permafrost by melting. However we do have some control over the risk, and we know that the eventual cost of operation is proportional to the degree of risk considered reasonable and acceptable. This is called a calculated risk.

Let me explain with a simplified example. Suppose that the construction of a pipeline from the Mackenzie Delta to

Chicago would cost $2.5 billion with a 20% chance of pollution over the next 25 years. If we set the danger of pollution at 15% the project can cost $5 billion, at 10% risk of pollution the cost may be $25 billions, while at 5% it may be as much as $100 billion. You will notice that the increase in cost rises more steeply as the acceptable danger of pollution is decreased. The same kind of thinking could be applied today to soil damage caused by tracked vehicles, a proposition which entails a painful decision for us, by which I mean not only the manufacturers of tracked vehicles but also the people of Canada and therefore their government.

The magnitude of the operation, and the social impact already felt by the nation as a whole, makes the Northern activities of our entire industry a matter of public interest. The government alone can make the decision as to what extent the oil industry must pledge itself to the safe exploration and development of this extremely sensitive area. Before arriving at this decision the government seeks opinion from other public bodies and from industry, as at this Conference.

There is a time for discussion, and a time for action; personally I am strongly of the opinion that now is the time for action. So far the government has no policy for the North

apart from a few restrictions here and there. I cannot speak on behalf of the whole industry but I can speak for my own Company, Bombardier Limited, and I must say that even we are effected by this lack of a clear policy. No one in his right mind will spend from a half to a million dollars in research only to find out that his product is rejected later because of a degree of ecological disturbance which was never specified in the first place. In my opinion, had the position then been as it is now, and if our founder Mr. Bombardier had contacted the different parties now involved before inventing his Skidoo, we would still be travelling by dog sledge. The question asked of the government is simple - what degree of risk can Canadians afford to take?

The answer to the question is not an easy one, but I believe it is now about time for us to know whether the government of Canada will permit the construction of pipelines and whether, and at what time of year, they will permit survey and exploration for this purpose. Unless the government takes a clear position on these issues, the development of the North will suffer and eventually stagnate. My company is involved in transportation in general and, although we are located some 4,000 miles from the scene of action, the effects of Northern

development, or the lack of it, are typical of those on the Canadian industrial scene.

Vehicles such as our Skidoo have to be adapted to specific soil conditions which, in the case of the Arctic, are new to us; it is only a coincidence that some of our vehicles happened to be suitable for the job. At the same time, I must emphasise that we have the technical and financial ability to develop the required equipment, and we know that new types will be needed for operation in permafrost. The question is, what kind? We could go ahead and develop the carrier which we believe to be the right one, or we could ask users what they want and, by this method, we might satisfy both our customers and ourselves by turning out a good job at the right price. But there is a third party between us and our customers, the government, who could forbid the vehicle we chose, perhaps for reasons of soil damage, reasons with which I might possibly agree.

Users and manufacturers are still awaiting a decision on this point and, although tests have taken place a Tuktoyaktuk last Summer, and Dr. Radford has made a study on tracked vehicles, so far as we know the government has not yet made public their report, nor published guidelines as to regulations which might

result. Some restrictions on Summer work have been announced but we do not know whether these are temporary or permanent. It takes three or four years to develop a new carrier through the stages of market survey, prototype design, production, trials and subsequent modifications which in total will ensure suitability for the harsh conditions of the Arctic. Not only do the manufacturers need time but, if in the interim users have to wait for their vehicles, then the money of both will be wasted and the entire rythm of Northern development will suffer as it has done in Alaska.

If existing carriers can do the job, then well and good. But if the government decides that existing tracked vehicles cause too much disturbance, and if as a result they ban them, then altogether new types such as those employing the air cushion principle will need to be developed. If this is the case, we must start work on them now because waiting costs money.

In conclusion, let me say that we are concerned with pollution, and that we take pride in supporting any law which may be enforced by government which is directed towards maintenance of the North as it is today - wild, beautiful, and a great place to live in.

VOLUME 2

SECTION 4 - WESTERN WATER TRANSPORTATION
(INCLUDING EFFECTS OF BUILDING
A MACKENZIE VALLEY PIPELINE)

CHAIRMAN: W. M. Gilchrist

PANELISTS: L. R. Montpetit

B. Willson

R. F. Allan

J. C. Underhill

"$H = \frac{V^2}{2g} + \frac{P}{w} + z = \text{Constant}$"

Bernoulli's Theorem for
liquid flow.

WATER TRANSPORTATION ON THE MACKENZIE RIVER SYSTEM AND THE WESTERN ARCTIC

By L.R. Montpetit, Executive Vice-President
Northern Transportation Company Limited

In keeping with the general theme and objective of this session, it is the intent of this presentation to stimulate discussion on the future of the Mackenzie River as an inland water route and to review the capability and services presently offered by its main operator, Northern Transportation Company Limited.

Public awareness of the large resource potential existing in the Arctic has been accentuated during recent years by the major oil discovery at Prudhoe Bay and by the intensive search now under way throughout the Mackenzie Delta, extending along the coastal region and into the Arctic islands.

As exploration and development of our northwestern frontier expands, so does the demand for transportation services of all types. This is clearly evident from the steady increase in freight shipments moved along the Mackenzie River system, especially since 1967. Much planning, both immediate and long range, has been done by Northern Transportation Company Limited to meet this challenge, but before discussing its specific role, some factual information regarding the marine highway itself would be of value.

The Mackenzie River system comprises one of the largest rivers in North America, with a length of 2500 miles and a drainage basin of some 700,000 square miles. With a runoff of about two hundred million acre feet per year, it drains a large part of the three most westerly provinces and the two Territories.

Water transportation services are provided from rail terminals at Waterways in Alberta and Hay River in the District of Mackenzie and encompass the region bounded by latitudes 56° to 72° north and longitudes 95° to 155° west (Figure 1). Because of a series of rapids at Fort Smith and on the Bear River, these services are subdivided into three general sectors, namely: Athabasca, Great Bear Lake and Mackenzie.

The Athabasca sector is located in the extreme southern portion of the region and consists of approximately 800 miles of water routes servicing the Athabasca River, Lake Athabasca, the Peace River, and that part of the Slave River south of Fort Smith. It services a number of communities whose industries are basically lumber, mining, trapping, and fishing. The season extends for 160 days from early May.

The Great Bear Lake sector presently consists of some 500 miles of water routes east of the Mackenzie River, and caters principally to recreational fishing camps, some trading outposts, and the mining industry. Navigation is possible from late July to early October for approximately 80 days.

The third and largest sector covers 3500 miles of route. This includes Great Slave Lake and the Mackenzie River from the end of rail at Hay River to Tuktoyaktuk, a distance of about 1100 miles, and 1500 miles of Arctic coastline extending from Colville River on the north coast of Alaska to Spence Bay on

the Boothia Peninsula. This sector also extends northerly to include the southern portions of Banks and Victoria Islands. The navigation season here varies between 75 days along the coast to 140 days on the river. River traffic usually begins about mid-June and, depending upon ice conditions, coastal movements are usually under way by the end of July.

As may be expected, ice and climate play a major role in coastal performance, while water levels in the southern latitudes are the controlling factor. Some indication of seasonal operations is given in Table 1.

Northern Transportation Company Limited, the only common carrier in the area to provide regular service to the three sectors, currently operates a modern fleet of 27 diesel tugs, two coastal ships, and 142 dual purpose barges. It maintains two receiving depots connected by rail and roadways at Waterways, Alberta, and Hay River, Northwest Territories, and during the navigation season supports fully integrated agencies with camps and terminals at Bushell in Saskatchewan and at Norman Wells, Bear River and Inuvik in the Territories. For coastal distribution a modern trans-shipping base is operated at Tuktoyaktuk, including a floating drydock capable of handling marine equipment of up to 4000 tons and 400 feet in length. It is fully operational in season and can provide complete marine repair and inspection services. To complement the overall operation, ship construction and maintenance facilities are

carried out at Hay River and Waterways, with additional ship-building yards when required at Fort Smith, N.W.T. The Company owns and maintains approximately 4000 lineal feet of steel-faced wharfs and provides employment to some 650 employees during the peak of operations. In 1970 it carried some 275,000 tons of dry and bulk cargo.

I am certain that everyone will agree that such an extensive transportation system, which provides a dependable service, even if seasonally restricted, is making a very significant contribution to the economic development of the Northwest Territories, and to the north in general. Because of its very nature, water transportation has and is pioneering the opening up of this country, and it will continue to be a most important practical method of freighting goods north of the 60th parallel. But it must be understood that water forms only a part of the total transportation complex. Swift transport of certain types of freight and people, as pioneered by the Canadian bush pilot, will continue to flourish and grow. The lack of roads, both all-weather and winter, causes some to feel that further development of river transportation should give way to massive expenditures in building a road network.

A balanced and rational approach to all practical transportation systems is required so that the benefits of one are not lost or deferred because of the demands of the other. The part of Canada under discussion is very demanding in terms of

cost for transportation when measured against its population. But these expenditures are highly justifiable if we are to seize the opportunity for developing our natural resources in our north while the marketing opportunities exist, with a consequent benefit to the entire nation and improvement in the standard of living of the local population.

Northern communities, in their efforts to improve their standard of living, have been largely dependent upon government support, but they could easily become self-sufficient if the oil and gas exploration now under way should become productive. The growing financial independence of the state of Alaska is a striking example of the prospects which may await our northern Territories.

Because of the serious drought conditions throughout the Mackenzie River drainage basin over the last few years, augmented by the effect of the Bennett Dam, there is a tendency to characterize the profile of the Mackenzie River as continuously narrow and shallow, and restrictive to navigation over its entire length. Nothing could be farther from the truth.

There are only five small sections of the Mackenzie River that are considered to be a constant hindrance to efficient water transportation. These are: Beaver Lake, Providence Rapids, Green Island Rapids, Sans Sault Rapids, and The Ramparts. Although the rock-formed rapids of the Sans Sault with its fast

waters, now under improvement, has so far imposed the most serious navigation difficulties and extreme operating hardships, the real capacity of the equipment and the river system is dictated by channel conditions in the first three sections mentioned. Because of their geographical location in the Mackenzie River, close to Great Slave Lake and the shipping terminal at Hay River, they affect the permissible draft loading of the barges and consequently determine the logistic capacity of the system.

To give some idea of the present restraining effect of this part of the river on the efficiency of the total operation, I would like to point out that the maximum draft achieved during the 1970 season, even considering high water periods, was only 60% of the design capacity.

Another result of the limitations of these channels is the time required to break up tows in order to relay single barges through these trouble spots, and on occasion even lightering to negotiate passage. This again seriously affects the efficiency of the existing equipment. All of this, naturally, is reflected in increased costs due to lower unit revenues.

It is now felt that investment in river channel improvements would be more productive per dollar spent than further expenditures in adding equipment to overcome the lack of river improvements.

Minimum channel requirement to allow an economical barge train through these problem areas is 8 feet of depth and 350 feet of clear width, increasing to 700 feet for turns and cross currents. This will accommodate a six-barge tow in a 3 x 2 pushing configuration, measuring 170 feet in width by 670 feet in length, and handling 10,000 tons of freight.

The cost to dredge this channel has been estimated at $16,000,000, and the project could be carried out in three years. Considering the fact that the benefits would be permanent, it is felt this investment in the present and future of the Mackenzie is reasonable and justifiable, particularly when the advantages are weighed against the vastness of the area it serves. Clearly, it would be to the lasting benefit of the northern population and prospective developers if these improvements could be undertaken as soon as possible. To delay further would have serious effects on the system as a whole.

Few, I believe, are aware that shipments of bulk oil account for 55% of the total water traffic, and will remain so long as petroleum products are the source energy for the north. This commodity acts as the most important stabilizer in the present one-way traffic pattern.

To attest to the competitiveness of water transportation, it is worth noting that after ten years of access to Yellowknife by all-weather road, we are still delivering all bulk products to this community by barge.

I think that it is also appropriate at this point to touch on the human aspect of the problem. If the requested river improvements are not made, the trans-shipping centre for the Mackenzie and western Arctic could conceivably shift downstream, with a consequent serious effect on the economic life of the town and population of Hay River.

The problem of channel passage has been of continuing concern to Northern Transportation Company, and in recent years it had to consider whether or not to develop Hay River as its main base of operations. After careful consideration, it decided to expand its Hay River facilities rather than to move its main marine base to Mills Lake, downstream from the major problem areas. This decision was not an easy one, and was finally made on the assumption that the river improvements in this area were considerably less expensive than extending the railroad north to Mills Lake, and that they would be done in time to meet the large increase anticipated in traffic.

Although our decision was a matter of economic judgment, it was also influenced by the effect it would have had on our resident employees, their families, and the town in general. However, in order to provide the services required and to remain viable, it is now essential that the river channel be improved.

Because of the oil strike at Prudhoe Bay and our conviction that the Mackenzie will emerge as the most practical artery for

the anticipated surge in oil and gas exploration and for the pipelines to bring the products to market, plans were made in anticipation of this new traffic.

Subsequently, during the last two years, four large vessels were added to the fleet. Three of these are twin screw combination ocean and river tugs of 4000 H.P., and the fourth is a quadruple screw single purpose river tug of 4500 H.P. Without a doubt the latter is the most powerful shallow draft vessel in North America, developing its total power at an operational draft of 3 feet 8 inches. We also built 24 dual-purpose barges measuring 50 feet by 200 feet in length, and eight barges of 56 feet by 250 feet, with a total deadweight capacity of 36,000 tons.

As a note of interest, all of this equipment was sectionally built in several plants and shipped by rail for assembly in our own shipyards at Waterways, Bellrock and Hay River. Twenty-eight freight cars were required to ship each of the larger barges.

Our terminal installations at Hay River were also expanded to include a syncrolift basin with a 65 foot x 250 foot platform with a maximum lifting capacity of 1770 long tons. The program also included the construction of a new bulk terminal capable of trans-shipping up to 10,000 tons per day with storage areas for approximately 30,000 tons. This terminal was built by joining two islands together and includes 15,000 feet of rail sidings and a water basin with 2000 lineal feet of loading wharf.

It was also decided to expand our facilities at Inuvik, which is important in the servicing of the Mackenzie Delta region by developing an additional 38 acre site for trans-shipping and storage purposes.

It is anticipated that next year will see the completion of all of these projects. Early discussions on the logistics of transporting pipeline materials indicated that additional storage facilities should be built on the rail line a short distance from our terminal, where the pipe could be accumulated, welded in double or triple joints, and then stored until required for shipment down river. The short distance between these two points would accommodate a regulated shuttle train service and permit the loading of barges directly from the rail cars, thus minimizing the time and cost of transfer operations. Our analysis indicated that given additional marine equipment, the shipment of pipe for the entire pipeline is totally feasible by barge through the port of Hay River.

Some uncertainty still exists on the source and form of the pipe itself and this, of course, reflects on our attempts to properly assess the transportation requirements. While 48 inch pipe is often suggested for the pipeline, we are informed that consideration is still being given to the possibility of transporting skelp rather than pipe in tubular form. This decision would naturally reflect greatly on the type of transportation equipment necessary to do the job efficiently. Secondly, and possibly more important insofar as it concerns water transportation,

is the place of manufacture. If the same source of supply is used as that for the proposed Trans-Alaska pipeline, then this would open the possibility that some of the shipments could be made more economically by ocean barge direct to Prudhoe Bay and Tuktoyaktuk, rather than through the usual routings. The fact that 165 miles of 48 inch pipe was successfully lightered and stacked on the tundra in Prudhoe Bay this past season is sufficient reason to accept the feasibility of this assumption. The short season prevailing in the Arctic would certainly impose tonnage limitations upon such a movement, but it seems practical and logical to accept that the northwestern sector of the line could be delivered by this route. The coastal trans-shipping base of Northern Transportation at Tuktoyaktuk is adequate for this type of unloading and storage operation. With these existing good port facilities it would only require sufficient lightering to negotiate the present 14 foot approaches. Because of the short lead time anticipated prior to the construction of the gas line, it is expected that the river will be found to be the most expedient and economical means of transporting the material to a series of sites where the pipe could be stored and further distributed by winter roads.

I believe it opportune at this time to discuss briefly the potential of the Mackenzie River as an access trade route to the north slopes of Alaska. At the request of British Petroleum Limited in 1963, our Company was asked to provide shallow draft equipment for the transportation of the first drill to the

Colville River, west of Prudhoe Bay. This operation was successfully carried out, and so was the resupply during the following years. Northern Transportation is therefore well aware of the potential in exporting their services.

With the advent of the major strike by ARCO and Humble Oil, it followed that the western route from Seattle via Point Barrow was extensively used, and I think everyone will agree that this was a natural development in view of the events. Nevertheless, we believe that because of the limitations imposed on navigation in the Beaufort Sea it is desirable that all water routes be maintained, and we feel confident that the oil companies will continue to recognize the value of the shorter Canadian route, with its higher dependability.

Cargo loaded at the Hay River rail terminal can be transported 1500 miles to Prudhoe Bay via a combination of protected inland and coastal waterways, as compared with 3700 miles of sea route from Seattle (Figure 2). Because of the shallow draft equipment used by the Canadian operators, we are usually able to reach Prudhoe Bay by sailing inside the grounded ice-pack some ten days earlier than the West Coast armada which must wait at Icy Cape for favourable winds to clear Point Barrow.

This advantage is substantial, both in terms of a longer season and the fact that we are not totally dependent on favourable wind to reach our destination. It can also be appreciated that a high frequency trip cycle is possible over the short distance of

245 miles from the Mackenzie delta, as compared with the much longer route of 3700 miles from west coast ports. In 1969 we transported about 26,000 tons of cargo to the American coast. Although we suffered a substantial setback to 8000 tons this past season, caused by reduced development brought about by the delay in construction of the TAPS line, we are confident that this is only temporary. It seems obvious that the American operators will continue to minimize their investment until they are assured of an economical method of transporting their product. The Manhattan experiment has indicated that Arctic tankers are not economically feasible at the moment, although technically possible. Therefore it appears mandatory that a solution to the pipeline dilemma be found as quickly as possible.

Some industries, particularly in western Canada, have long realized the opportunity and potential offered by the development of the north slopes of Alaska, and drilling companies, together with manufacturers of prefabricated camp units, track vehicles, and off-highway trucks, have found a ready market for their products and services. It is our belief that other local businesses will effectively follow their lead as the Mackenzie water route offers the most economical access to this trade.

It seems doubtful that the first oil line from Alaska will go through Canada, but it is likely that the Mackenzie valley will be the route for the first gas carrier to the United States midwest and eastern seaboard. Should the indicated potential

of the Canadian north become a reality, it could conceivably support a second pipeline, an event of major importance for the Mackenzie.

It might now be in order to say a few words on the present water transportation rate structure.

The Mackenzie River system, as distinct from the western Arctic, first came under the jurisdiction of the Board of Transport Commissioners in 1946. Subsequently, maximum standard mileage rates, including arbitraries for the Great Bear and Slave Lake areas, were established, and by means of a series of reclassifications and new tariffs, filed between the years 1951-59, substantial reductions were effected. Western Arctic rates were also greatly reduced during this period, and by 1965 overall decreases ranged between 20% and 28%.

Existing rates, which have never included an increase, are still well below the permissible level of tariffs established by the Commission two decades ago, and reflect the decision of the Company to pass on to its customers all major benefits derived from improvements in equipment and operational methods, as well as growth in traffic.

The high cost of financing new equipment and facilities during recent years, together with continuous increases in operating costs, have caused the Company to re-examine this policy, and although we have resisted the alternative of

applying for rate increases, we can see no probability of further general reductions. To meet this inflationary trend we are depending on additional traffic and improved water conditions.

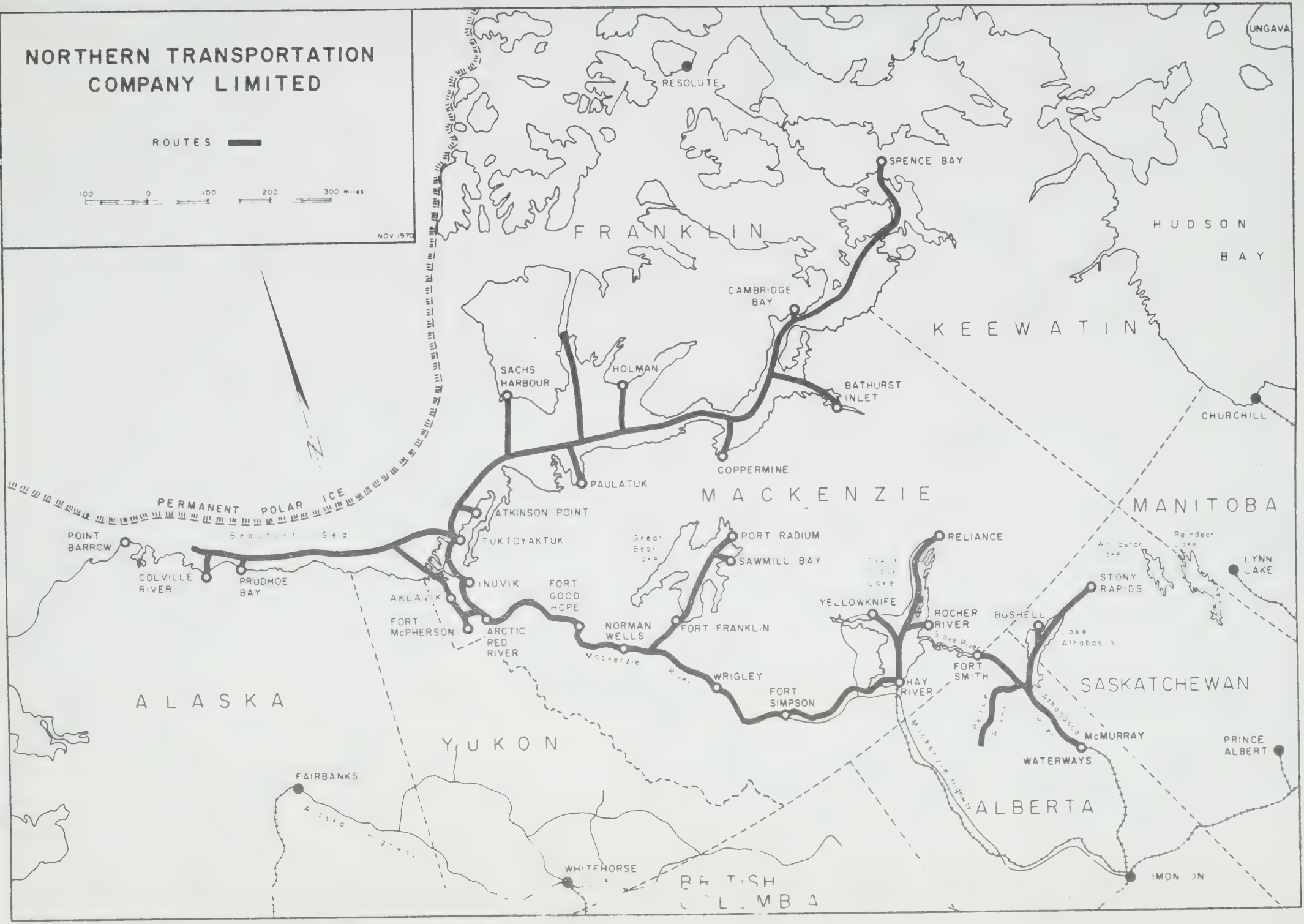
In closing, I would like to say that Northern Transportation Company is looking to the seventies with great enthusiasm and confidence in the future of the Mackenzie water route, and that we are certain it will be a period of exciting growth and increasing prosperity for the whole Canadian northland.

TABLE 1: AVERAGE SHIPPING PERIODS ON MACKENZIE WATER ROUTES

FROM	TO	PERIOD	DAYS
WATERWAYS, ALBERTA	ATHABASCA RIVER	MAY 5 - OCT 20	168
	PEACE AND SLAVE RIVERS	MAY 18 - OCT 20	155
	LAKE ATHABASCA	JUNE 1 - OCT 20	142
HAY RIVER, N.W.T.	GREAT SLAVE LAKE AND UPPER MACKENZIE RIVER	JUNE 15 - OCT 20	127
	GREAT BEAR LAKE	JULY 15 - OCT 10	80
	LOWER MACKENZIE RIVER	JUNE 20 - OCT 5	107
	TUKTOYAKTUK	JULY 5 - SEPT 25	82
	ARCTIC COASTLINE	JULY 15 - SEPT 25	72

NOTE: Depending on type of vessel, the minimum average sailing time between Hay River and Tuktoyaktuk (1122 miles) is:

	Continuous sailing	With stops and relays
Northbound	4½ - 5½ days	9 days
Southbound	7½ - 9½ days	12 days



WESTERN WATER TRANSPORTATION - 253

Figure 1

Figure 2

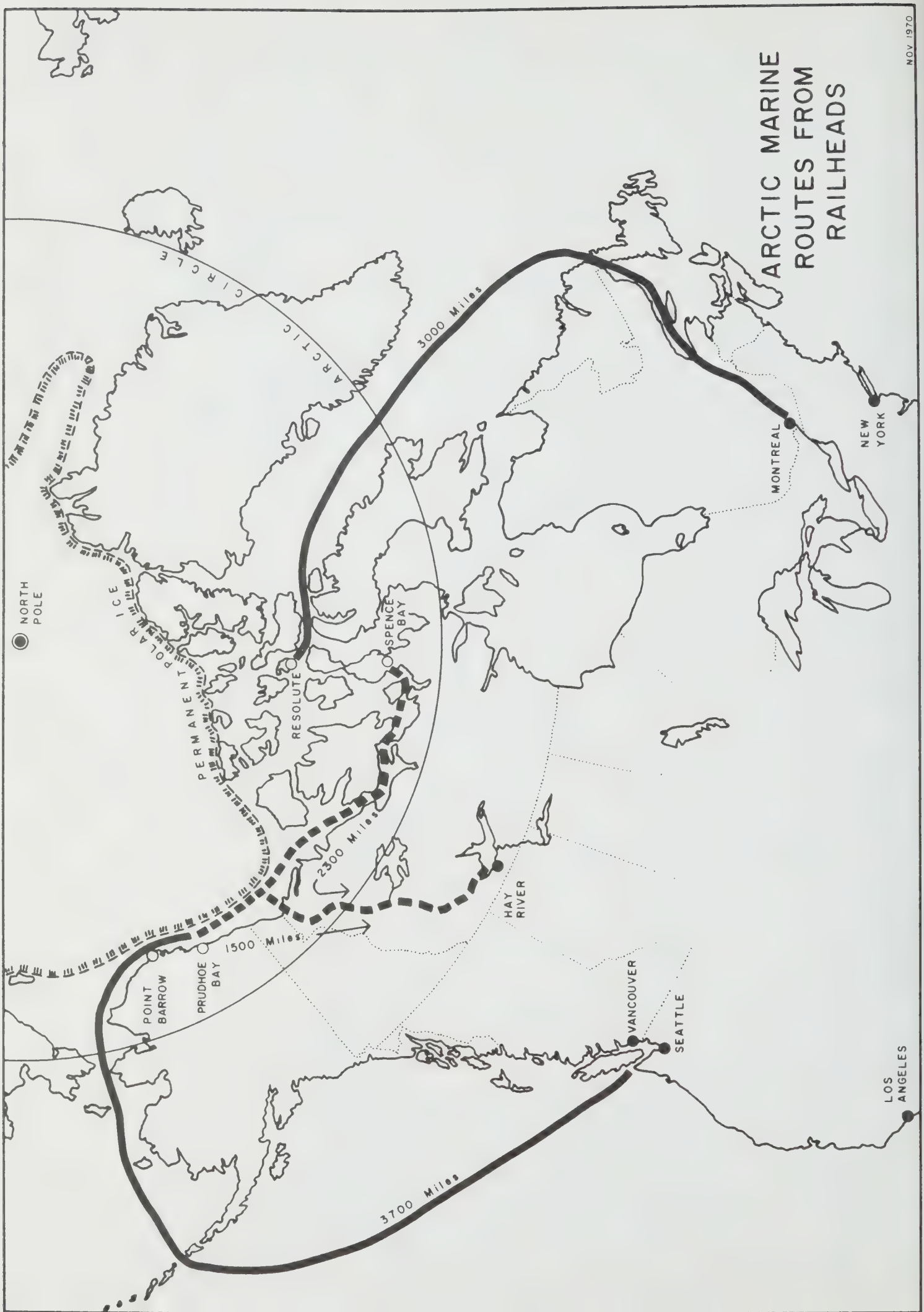
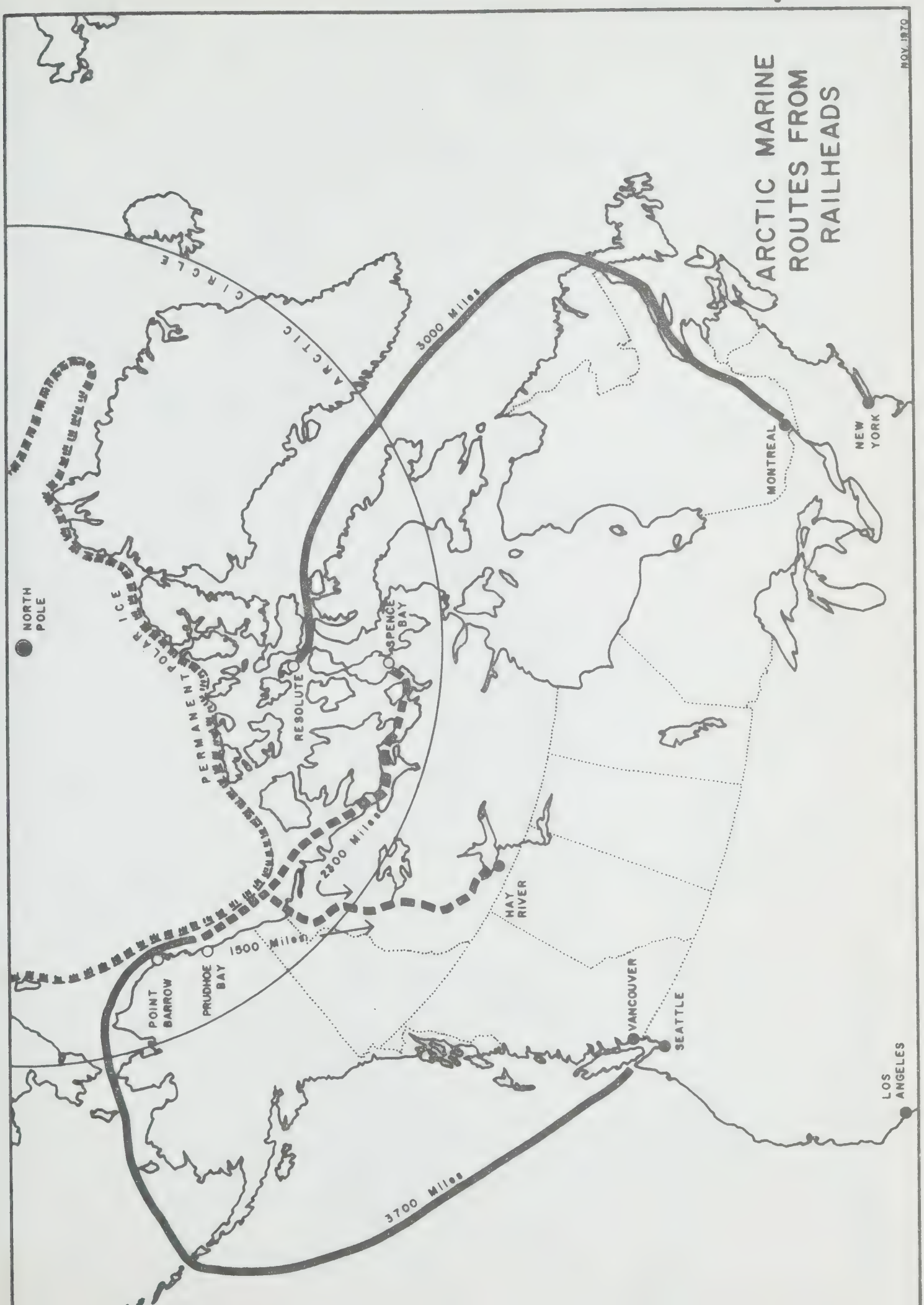

ARCTIC MARINE ROUTES FROM RAILHEADS
NOV 1970
ARCTIC CIRCLE
NORTH POLE
PERMANENT POLAR ICE
POINT BARROW
PRUDHOE BAY
RESOLUTE
SPENCE BAY
HAY RIVER
MONTREAL
NEW YORK
VANCOUVER
SEATTLE
LOS ANGELES
1500 Miles
2300 Miles
3000 Miles
3700 Miles

Figure 2


ARCTIC MARINE ROUTES FROM RAILHEADS
NOV. 1970
ARCTIC CIRCLE
NORTH POLE
PERMANENT POLAR ICE
RESOLUTE
SPENCE BAY
3000 Miles
2200 Miles
1500 Miles
POINT BARROW
PRUDHOE BAY
HAY RIVER
MONTREAL
NEW YORK
VANCOUVER
SEATTLE
LOS ANGELES
3700 Miles

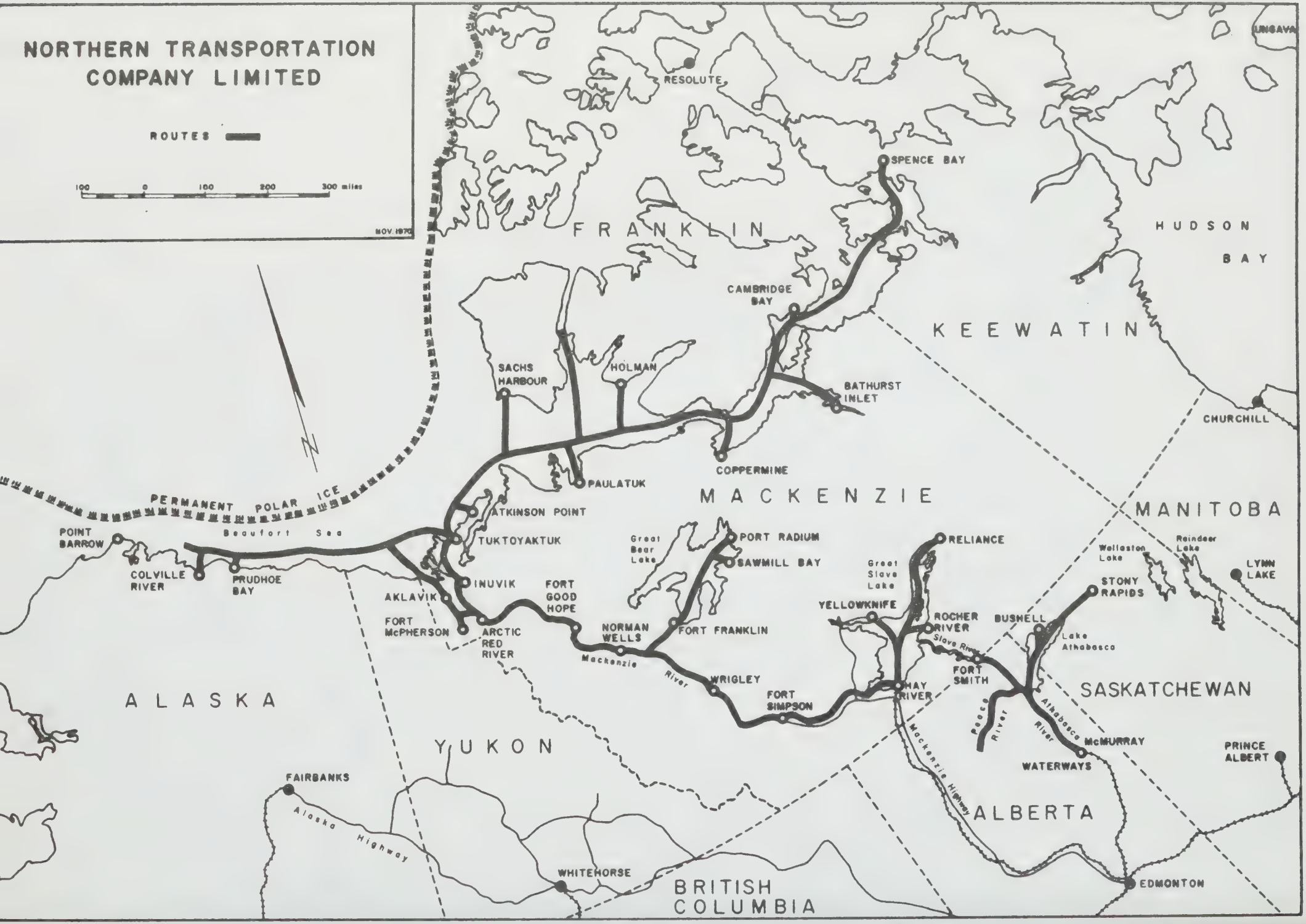

NORTHERN TRANSPORTATION COMPANY LIMITED
ROUTES
100 0 100 200 300 miles
NOV. 1970
RESOLUTE
SPENCE BAY
FRANKLIN
HUDSON BAY
CAMBRIDGE BAY
KEEWATIN
SACHS HARBOUR
HOLMAN
BATHURST INLET
CHURCHILL
COPPERMINE
PAULATUK
PERMANENT POLAR ICE
Beaufort Sea
MACKENZIE
MANITOBA
ATKINSON POINT
POINT BARROW
TUKTOYAKTUK
Great Bear Lake
PORT RADIUM
SAWMILL BAY
RELIANCE
Great Slave Lake
Wollaston Lake
Reindeer Lake
LYNN LAKE
COLVILLE RIVER
PRUDHOE BAY
INUVIK
FORT GOOD HOPE
AKLAVIK
YELLOWKNIFE
ROCHER RIVER
BUSHELL
STONY RAPIDS
FORT McPHERSON
ARCTIC RED RIVER
NORMAN WELLS
FORT FRANKLIN
Slave River
Lake Athabasca
Mackenzie River
WRIGLEY
FORT SMITH
HAY RIVER
FORT SIMPSON
SASKATCHEWAN
ALASKA
YUKON
Peace River
Athabasca River
McMURRAY
PRINCE ALBERT
Mackenzie Highway
WATERWAYS
FAIRBANKS
Alaska Highway
ALBERTA
WHITEHORSE
EDMONTON
BRITISH COLUMBIA

Figure 1

CURRENT OUTLOOK FOR PIPELINES OUT OF THE ARCTIC

Presented by

B. F. Willson, President
Canadian Bechtel Limited, Toronto, Ontario
and Director, Mountain Pacific Pipeline Ltd.

at

Arctic Transportation Conference, Yellowknife, N.W.T.
December 8, 1970

The vision of a new era - a pipeline era - in the history of northern Canada has captured the imagination of a sizeable segment of the population of North America. The subject has received much publicity and has been the basis for frequent statements by cabinet ministers on both sides of the Canada-U.S. border. As far as Canada is concerned, it seems that most governments and numerous departments in Ottawa want to get into the act. The question of Canadian sovereignty is involved and this is a subject that stirs the political instincts of any politician worthy of the name. On November 5th in Edmonton, the Hon. Jean Chretien commented that in 1970 it would have been simpler to have a cabinet meeting in Yellowknife than in Ottawa.

In point of fact, the North has been opening up at quite a rate in advance of the recent surge in oil and gas exploration. The exploration activities of mining companies, coupled with the construction of continental radar defense networks and other contributions by governments, have resulted in greatly improved transportation and communications facilities during the past two decades. The stepped-up search for hydrocarbons has merely provided additional impetus to the rate of development. While the North presents many obstacles to overcome, it is not considered the virtually impassable barrier it once was believed to be.

There is a continuing prodigious demand in North America for crude oil and natural gas. The continental demand for fossil fuels maintains a rather steady growth rate of about 4% per year. The growth rate for Canada is even higher than this. The present demand for crude oil in the U.S. and Canada combined is about 15 million barrels per day or approximately 5 billion barrels annually. Natural gas is being consumed at the rate of about 22 trillion cubic feet each year, as we enter the 1970's.

The established reserves of crude oil and natural gas in the lower forty-eight states are declining. When matched against the increasing demand, the "life index", i.e. established reserves divided by the present rate of production, of these reserves is declining even more rapidly.

Indeed the natural gas supply situation in North America is becoming critical. Reserves in the lower forty-eight states appear to have peaked out. At the end of 1969 in spite of significant additions in the prior 24-month period, they stood at 275 trillion cubic feet compared with 290 trillion cubic feet two years previously. In 1969, production in the U.S. exceeded additions to reserves by 12 trillion cubic feet. The "life index" has dropped from 21.8 years in 1956 to 13.3 years at the end of 1969.

Similar figures can be developed for conventional crude oil reserves. The reserves/consumption ratio is even less for crude oil than that for natural gas.

FIRST, let's first look at recent northern oil developments.

Against this background of very large and still increasing demands and declining "life indices" we have the exciting new discoveries in the Arctic on the North Slope of Alaska and the Mackenzie Delta Region. Certain information regarding the Prudhoe Bay reserves is now being made public. Mr. Jim Wilson, Vice President of Atlantic Richfield, in a recent address gave his firm's estimate of the Prudhoe Bay oil reserves as 31 billion barrels in place, with 12.5 billion barrels considered recoverable. Humble, one of the other partners in the North Slope development, has estimated the

recoverable Prudhoe Bay oil reserves as 10 billion barrels. While these estimated reserves are substantial, they represent only about two years' supply at the current rate of North American demand.

Imperial Oil Limited, whose discovery at Atkinson Point on the Mackenzie Delta excited the industry in January of this year, has not published any estimate of recoverable reserves related to this new find. However, it is known that Imperial's four step-out wells drilled since the discovery have been abandoned as non-productive. Atkinson Point by itself does not appear to be a second Prudhoe Bay.

With respect to northern Canada, the surface has barely been scratched in the search for new reserves of hydrocarbons. There are high hopes that the Northwest Territories and the Arctic Islands sedimentary regions will provide oil reserves at least equivalent to the Alaska discoveries. New discoveries are essential, of course, for the continued growth of the so-called "conventional" oil industry.

The attached Figure 1. shows the potential hydrocarbon producing areas of Canada, i.e. the parts of the country underlain by sedimentary rocks, considered favourable for the accumulation and entrapment of oil and gas. At the recent Northern Development Conference in Edmonton, we heard some rather astronomical numbers as to the potential recoverable reserves of the Mackenzie Basin and the Arctic Islands. A. N. Edgington, President, J. C. Sproule and Associates Ltd., gave his estimate for oil in this area as 100 to 150 billion barrels and for gas as 500 to 750 trillion cubic feet. To give some perspective to these quantities, it can be pointed out that Canada's present reserves of conventional crude oil amount to about 11 billion barrels and for gas approximately 55 trillion cubic feet.

Thus, according to Mr. Edgington, in that part of Canada North of 60 we have ten times the potential of what has been proven to date South of 60. We certainly hope he is right.

However, the rate at which this potential is discovered and developed will govern the timing for the construction of large diameter pipelines out of the Canadian Arctic. To date on our side of the Alaska-Yukon border results from exploratory drilling have been quite disappointing.

Three alternatives have been studied for bringing the new Alaska crude oil reserves to major North American markets. These can be illustrated by reference to Figure 2.

(i) The Trans Alaska Pipeline (Prudhoe Bay to Valdez), plus tanker transportation to the Puget Sound area and other possible markets, plus Trans America Pipeline (Seattle to Chicago).

(ii) The Mackenzie Valley oil pipeline from Prudhoe Bay to Edmonton, which would require augmented Trans Mountain and Interprovincial Pipe Line systems to transport production to the major consuming market areas.

(iii) Transportation by supertanker - an alternative studied by Humble Oil Company's "Manhattan". In its studies, Humble visualized the North West Passage being plied by a fleet of twenty 300,000 ton supertankers costing $2 billion and delivering 1.5 million barrels per day to the East Coast by the mid 1970's. Recently the company announced that it now considers transportation by pipeline as the more economical method for moving the North Slope crude and has therefore abandoned - for the time being at least - the tanker alternative.

The Trans Alaska Pipeline Project has been frustrated to date by the inability of its sponsors to obtain the necessary government permits and authorizations. This delay evolves largely around the question of steps necessary to protect the northern environment during construction and operation of the line. One would expect that, as a result of experimental work now being conducted in Alaska, the pipeline backers will be able to satisfy the Federal and State Governments involved that a particular design is sound and thereby overcome the objections of the conservationists. It appears likely that after two years' delay the construction of the Trans Alaska pipeline should get underway in earnest in 1971, with completion by late 1974. At last month's Northern Development Conference in Edmonton, Senator Gravel of Alaska predicted construction on the access roads would commence by April 1, 1971.

What is proposed by Trans Alaska is a 48-inch line, 800 miles in length, with a capacity when fully powered of 1,800,000 barrels per day. The cost is estimated at approximately $1500 million - a staggering sum.

Once the Trans Alaska line is built, we can expect a second pipeline up the Mackenzie Valley to be more remote in terms of time. An oil pipeline following the Mackenzie route, of necessity, will be dependent upon the finding and development of very substantial reserves in the Canadian Arctic. To date the Atkinson Point well provides encouragement that these reserves exist; however, many more discoveries will be required before a large diameter pipeline becomes economically feasible. Also at the Edmonton conference, David Furlong, General Manager of the Canadian Petroleum Association, indicated it will require three Middle East type oil fields each capable of producing 500,000 barrels per day to justify a Mackenzie Valley pipeline out of the Canadian Arctic. Clearly many exploration successes are necessary before such a project can become a reality.

Mackenzie Valley Pipe Line Research Limited, a consortium headed by Trans Mountain Oil Pipe Line Company and Interprovincial Pipe Line Company, has already spent $2.5 million on a test loop at Inuvik and route selection studies in anticipation that ultimately a Canadian pipeline following generally a route up the Mackenzie will be required. In view of the extensive areas of sedimentary rock remaining to be explored, we can expect that the Mackenzie Valley oil pipeline will ultimately be built but the timing is uncertain.

It might be appropriate at this point to discuss briefly some of the design and other considerations peculiar to pipelines in the Arctic environment.

To carry out operations in remote and hostile surroundings such as the Arctic requires a high degree of logistic skill and planning to insure success. The Arctic presents new and significant problems in design, construction and logistics for pipelines, particularly when "detrimental" permafrost is encountered. Detrimental permafrost is defined as permanently frozen, fine grained, high moisture content soils which in thawing would degrade to an unstable condition.

Of primary importance in the design of any pipeline system through Arctic and sub-Arctic regions is the consideration of the possible effect that the pipeline would have on the environment of which ground containing permafrost is one of the most fragile.

Two of the more promising methods for designing and constructing through areas containing detrimental permafrost are:

- The pipeline encased in and supported on a gravel berm.

- The pipeline elevated on pile bents.

The objective of the above-ground systems is to prevent the deterioration of detrimental permafrost. Any design must also provide means for wild life to cross the pipeline and must not adversely alter natural drainage.

When the gravel berm method is used the berm must be designed so its thickness will add sufficient insulating values to that used on the pipeline to insure that the permafrost remains in its natural state. Experiments indicate this gravel bedding, depending upon the conditions encountered and the insulating values required, will be from 2 feet to 5 feet or more thick.

The pile bent alternative elevates the pipeline above the natural ground so the permafrost is not degraded. The piles are drilled in and frozen back to such depth as to support the entire load by the adfreeze skin friction on the pile. Indications are that timber piles with cold temperature steel pile caps are the best materials. The design and resulting alignment configurations will be for an unrestrained pipeline. This means that the pipe will be free to move in a controlled fashion to accommodate the considerable expansion and contraction experienced over the wide temperature and pressure conditions.

Test facilities were constructed by Canadian Bechtel Limited for Mackenzie Valley Pipe Line Research Limited at Inuvik, N.W.T., to determine the physical, technical and practical aspects of construction, operation and maintenance of a large diameter hot crude oil pipeline system in detrimental permafrost areas of the Arctic.

A diagram of the Inuvik Test Facilities is attached (Figure 3.). Both berm and pile bent types of construction were used for one of the lines. Another smaller diameter line was buried.

During the six-month operation period the temperature rise beneath the berm caused by circulating heated oil was observed to be appoximately the same as the temperature rise at the datum caused by seasonal temperature changes. It appears that subgrade temperatures will be raised by hot oil.

The observed difference between datum temperatures and subgrade temperatures beneath the pile supported pipe is related to the shading from the low angle sun rays. For the pile supported system it is to be expected that the integrity of the permafrost soils will be maintained - in fact the subgrade temperatures will probably be lower than would otherwise be the case where this system is employed.

As a result of the test at Inuvik, it appears that directly burying a hot oil pipeline in detrimental permafrost will not be satisfactory, and that some other design will have to be employed for this type of soil.

It is highly desirable that we take advantage of world-wide experience in finding the best solutions to the problems presented by permafrost. Last month I was privileged to be a member of a five-man group of senior Bechtel people invited by the Russians to visit the U.S.S.R. and inspect their Arctic hydro-electric and pipeline installations. The trip was the experience of a lifetime and by itself could provide subject material for a lengthy address.

In summary, it appears that the Soviet's experience with permafrost conditions is considerably broader than ours. Outside the city of Yakutsk in northeastern Siberia (62^{o} North Latitude) we inspected a 220-kilometer gas pipeline which had been operating for the past two years in an area underlain by continuous permafrost. For about half its length the pipeline was above-ground with the balance buried in the active layer with about 30 inches of cover. No similar installation exists in the Canadian Arctic at present. The Soviets strongly recommended the buried pipeline approach vis-a-vis the above-ground type of installation wherever it could be done without damage to the environment. The delegates at the Yellowknife conference might be interested in colour slides of this installation taken during our visit.

Getting back to our present thinking regarding the engineering of Arctic pipelines, pump stations should be designed for remote and unattended operation. The design should probably use conventional centrifugal-type pumps driven by aircraft-type turbines compatible with a modular design for construction and maintenance.

All control, essential flow and pressure information should be automated and transmitted via a microwave system to a dispatcher for the service required. This is consistent with the practices which have proven satisfactory with other Arctic installations.

As required by the Guidelines, every effort should be made to use indigenous personnel including Eskimos and Indians both for construction and operation. They must be qualified for the skilled positions such as welders, machine operators, engineers, etc., for which considerable training will be required. However, there should be little difficulty in using them for the unskilled jobs in clearing, road building and other work, although patience must be exercised.

NEXT let us look at the natural gas picture in the Canadian Arctic.

Here also the prospects for immediate construction of large diameter pipelines appear somewhat remote, but are better than those for a Canadian crude oil line. No large diameter gas pipeline can be constructed until an oil pipeline has been completed and large quantities of oil are being produced from the North Slope fields.

Excepting for the moment Panarctic's gas discovery on King Christian Island, from the supply point of view, the only uncommitted major reserve on the northern horizon is the Prudhoe Bay solution gas and related gas cap. Limited data is available on the extent of the reserve. Thomas R. Marshall, Jr., Chief Petroleum Geologist for the Division of Oil and Gas, U.S. Department of Interior, has been quoted as saying the casinghead gas reserves amount to about 10 trillion cubic feet. Presumably this does not include the gas cap reserves which could and probably do result in a doubling of this figure. Incidentally, a 20 trillion cubic feet reserve is less than a one year supply for the U.S. at the present rate of demand.

The rate at which this gas might become available is one of the uncertainties in the situation. For example, if crude oil production at Prudhoe Bay reached 1 million barrels per day by 1976, the solution gas (produced unavoidably with the oil) after treatment for removal of the inerts would be in the order of 650 to 700 million cubic feet per day. Whether this gas will be available for sale or whether it will be needed for repressuring in order to maximize the ultimate oil recovery is still not decided. We do know that the Prudhoe Bay producers are studying this repressuring alternative.

In any event, initially gas throughputs of the order of 1500 million cubic feet per day (1.5 bcf/d) to 2 billion cubic feet per day will be required for the economic transmission of gas through large diameter (48-inch) long distance pipelines. In order to minimize transmission costs, the pipeline should be designed to transport in the order of 3 bcf/d as the optimum. Economies in transmission will be essential in the marketing of Arctic reserves if this gas is to be reasonably competitive in the load centres of North America with other fuel alternatives.

It is therefore obvious that either a dedication of a substantial part of the reserves in the gas cap at Prudhoe Bay or significant additional gas discoveries or both will be required before any pipeline project can be firmed up. Recent newspaper stories and other published material initiated by one of the three contending projects tend to give the impression that a gas pipeline from Prudhoe Bay to Alberta is feasible in the near term. With all due respect, this just does not appear to be the case.

Three groups have announced plans to study pipeline projects which, if built, would transport gas from Alaska to major consuming markets in the United States. In order of their public announcements, these are:

(i) The Mountain Pacific Project. This is sponsored by Westcoast Transmission Company Limited of Vancouver and the Bechtel organization including Canadian Bechtel Limited.

(ii) Northwest Project Study Group. This effort is spearheaded by TransCanada PipeLines Limited. Partners include two U.S. gas transmission companies and the three producing companies with the major interest in Prudhoe Bay reserves.

(iii) The Alberta Gas Trunk Line Company Limited, whose scheme is supported by Consolidated Pipeline Company, a subsidiary of Northern Natural of Omaha. Consolidated's bid to export Alberta gas to the United States was recently turned down by the National Energy Board.

The Mountain Pacific Project, as presently envisaged, would consist of a 48-inch ultra high pressure pipeline, 1085 miles in length, running from Prudhoe Bay to a bifurcation point near Fort Liard, N.W.T., plus a 938-mile, 40-inch line south from Fort Liard to the Canada-U.S. border at Kingsgate, B.C. It assumes that part of the Alaskan gas would be made available at the bifurcation point to a second 40-inch line running southeast towards Chicago. The Mountain Pacific project would serve markets in southern British Columbia and the western Pacific states of Washington, Idaho, Oregon, Nevada and California, with the southern terminus of the line near Los Angeles.

The Northwest Project Study Group is studying the technical and economic feasibility of a large diameter line from Prudhoe Bay to Chicago. It would follow a route similar to Mountain Pacific to a point near Fort Simpson from where it would angle in a southeasterly direction past Winnipeg to the U.S. mid-west.

The northern portion of the Alberta Gas Trunk Line scheme would follow a route similar to that being studied by Mountain Pacific and Northwest Project Study Group. As announced, it would connect with the northern portion of Trunk Line's existing gathering system in the Province of Alberta. Once into the Trunk Line system, gas could be routed to markets served by pipelines now tapping Alberta reserves.

The Northwest Project Study Group in announcing its $12 million study in July of this year said "neither our group nor anyone else is in a position now to say that a project of this scope and magnitude is feasible or financeable or to announce early construction plans." This is certainly the case and for anyone to indicate otherwise is quite misleading. It should be emphasized that the market demands proposed to be served by the Mountain Pacific project are so great that a pipeline from the Arctic can and will be financed and built just as soon as the availability of the required volumes of gas is assured. This may also be true of others of the projected pipelines.

NOW a word about Canadian Guidelines.

In August, the Canadian Ministers of Energy, Mines and Resources (The Hon. Joe Greene) and Indian Affairs and Northern Development (The Hon. Jean Chretien) issued what was referred to as a set of Guidelines which will govern northern Canadian pipeline developments. These Guidelines cover such aspects as a limitation on the number of pipelines to be built; the type of transportation service to be performed (i.e. common carrier versus contract carrier); regulation (pipelines built are to be governed by the National Energy Board Act); Canadian content (maximum Canadian participation is encouraged for ownership, financing, supply of materials and personnel); preservation of the northern environment (as demonstrated by research programs); and employment of indigenous people (during both the construction and operating phases).

Apart from the common carrier requirement, the Guidelines appear logical and not too hard to comply with. At the present time, it is a bit difficult to say how a pipeline company could give a firm undertaking to carry all oil or gas which might be tendered by a producer at any time in the future (the common carrier approach). Take-or-pay throughput arrangements for both buyers and sellers involving virtually the entire capacity of the line will likely be required in connection with the financing of the project. If this is so, there would be limited carrying capacity available for new discoveries. However, it is really too early to determine whether or not this Guideline will impose a problem. In normal circumstances, pipeline operators are keen to expand capacity wherever a willing buyer and a willing seller situation exists.

CONCLUSIONS

To summarize, it would appear that:

(i) A start will be made on the construction of the Trans Alaska Pipeline System in 1971 with completion some time in 1974.

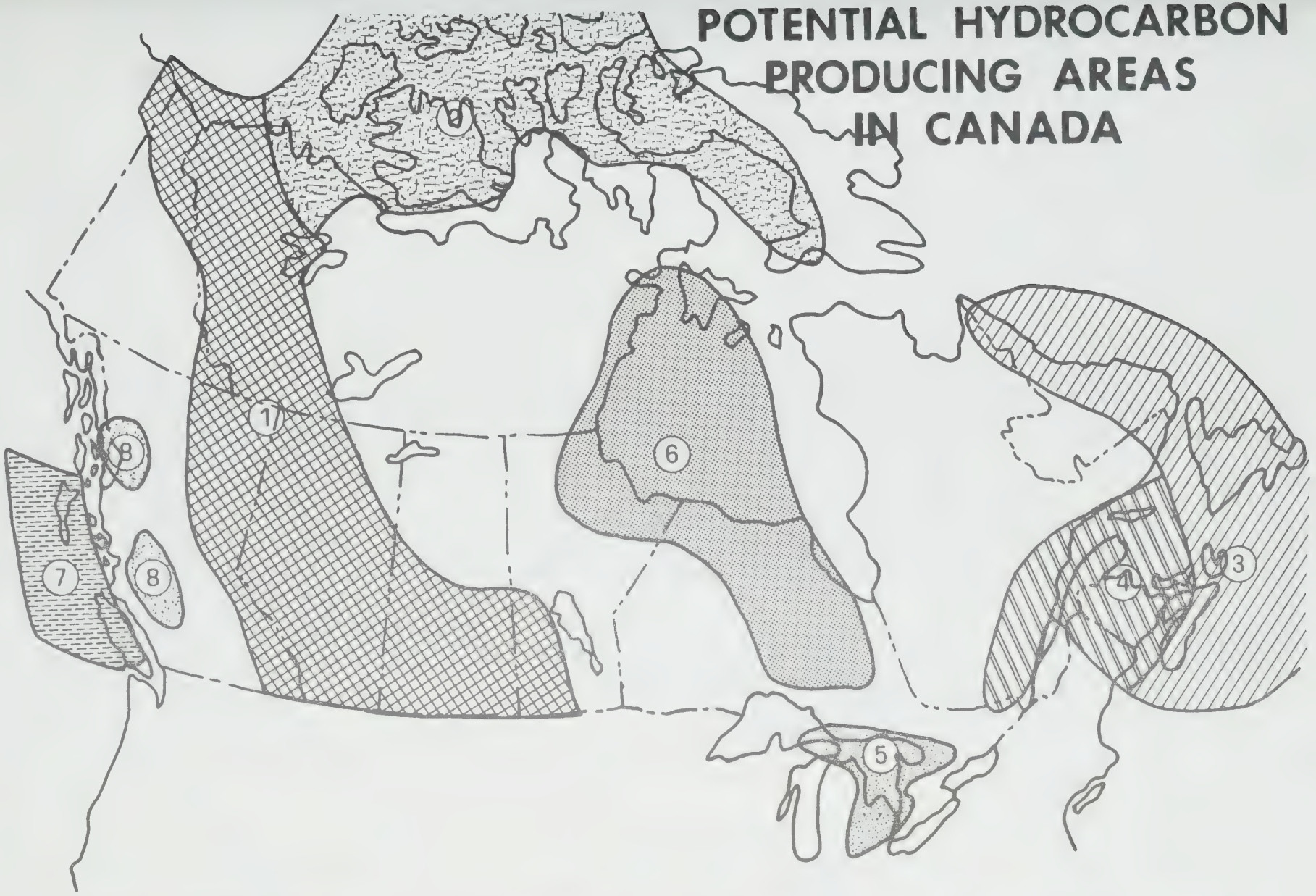
(ii) A Mackenzie Valley oil pipeline is some distance in the future - the timing will be entirely dependent on future Canadian Arctic discoveries.

(iii) A large diameter pipeline bringing Prudhoe Bay gas reserves to U.S. markets is not economically feasible until there is available for transportation from Prudhoe Bay or from other northern areas tributary to such pipeline volumes in the order of 2 billion cubic feet of gas per day assured for at least a period of twenty years. Development of substantial additional amounts of gas (preferably from fields not associated with oil production) will likely be necessary before an Arctic gas line can become a reality.

(iv) The growing shortage of gas supplies, together with the substantially higher cost of finding, developing and transporting northern gas to the major market areas will add significantly to the delivered price which consumers will pay in the future. At the same time, the inherent advantages in natural gas as a fuel will enable it to command a premium price in the energy market.

In conclusion, I would like to stress again the great potential of the Arctic. But this potential can only be realized through the combined efforts of Canadian and American industry working closely together under enlightened government sponsorship and regulations.

FIG. 1.



1. WESTERN CANADA SEDIMENTARY BASIN
2. ARCTIC ISLANDS
3. EASTERN CANADA - OFFSHORE
4. GULF OF ST. LAWRENCE
5. SOUTHERN ONTARIO
6. HUDSON BAY
7. WEST COAST
8. BRITISH COLUMBIA INTERIOR

FIG. 2

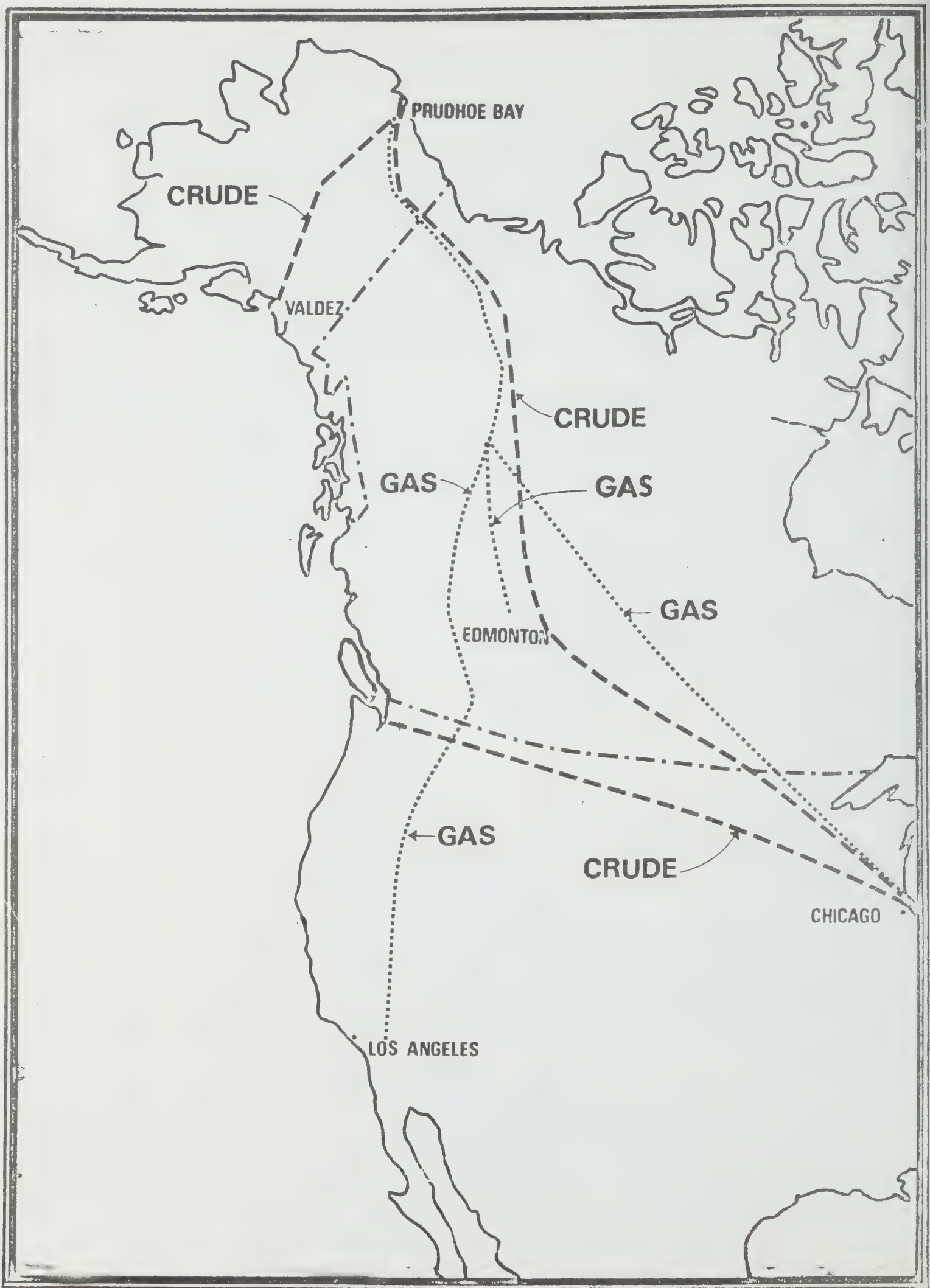
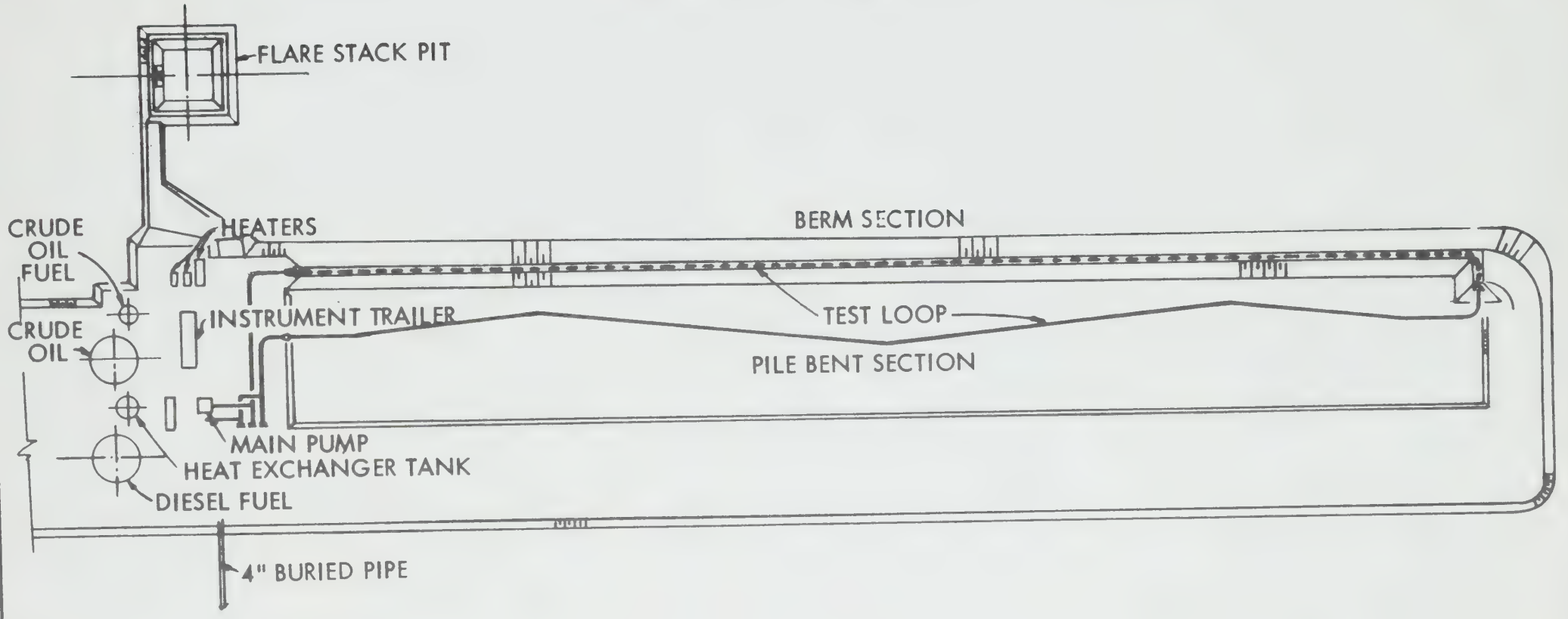
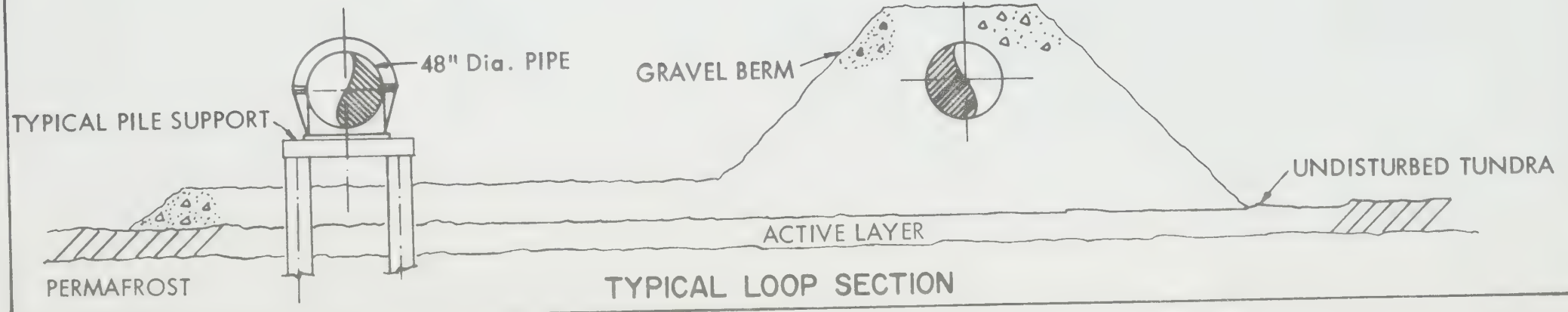

PRUDHOE BAY
CRUDE
VALDEZ
CRUDE
GAS
GAS
GAS
EDMONTON
GAS
CRUDE
CHICAGO
LOS ANGELES

FIGURE 3.

INUVIK TEST FACILITY





TYPICAL LOOP SECTION

CURRENT DEVELOPMENTS IN DESIGN OF TUG/BARGE TRANSPORT FOR THE MACKENZIE RIVER

Robert F. Allan

President, Robert Allan Ltd.
Naval Architects
Vancouver, B. C.

Introduction

The Mackenzie River is now and is likely to remain a great natural route for the transport of bulk commodities and general freight. It is difficult for navigation, the operating season is short and, consequently, freight rates are high. At present the only alternative is air transport but it is to be anticipated that eventually road and rail transport will reach out and provide keen competition.

At the moment the basic problem is movement of tonnage but in the future freight rates and consequently efficiency of operation will be of increasing importance.

Both problems, that of increasing tonnage, and that of improving efficiency, relate to current developments in towboats and barges.

In Section I we have outlined some background information relating to the river. In Section 2 we discuss the barge flotilla and possible steps to increase tonnage throughput. In Section III we discuss towboat design and some modern innovations in which we have been involved, including the design of the latest addition to the Northern Transportation Co. Ltd. fleet, the M.V. "Vic Ingraham".

Section I

BACKGROUND INFORMATION

Critical Area of Navigation

The areas critical to navigation on the Mackenzie are, in order from Great Slave Lake:-

Beaver Lake

An area of little current but shallow water. Navigable channel in order of 5 to 8 feet depth.

Providence Rapids

Water depths in order of 15 to 25 feet but fast current, generally about 6 mph but indications up to 11 mph.

Green Island Rapids

Narrow and intricate channel, current to 6 mph.

Blackwater

For a distance of 66 miles current strong and turbulent, flowing 6 to 8 mph.

Sans Sault Rapids

Boulder shallows, water depths in order of 4 to 8 feet, current in order of 3 to 4. 1/2 mph. Many bottom hazards.

Ramparts Rapid

During periods of low water a distinct drop forms over a distance of about 500 yards through which current flows 6 to 7 mph.

Of these, the one most critical to navigation is the Sans Sault Rapids. This is an area where strandings and serious damage to towboats and barges occur frequently.

Critical Areas of Navigation (Continued)

The fast waters of Ramparts, Blackwater, and Providence Rapids are serious obstacles to upstream navigation. It is not always possible to navigate a full flotilla through these waters and time is consumed by having to relay barges. Work is going ahead towards improving the channel at Sans Sault and it is hoped that the full benefit may be felt in the 1972 season.

Section II

GENERAL CONSIDERATIONS RELATING TO BARGE FLOTILLAS

Limitations Upon Flotilla Size

The physical characteristics of the river impose limits of dimension on a flotilla as follows:-

1. Length is limited by considerations of manoeuverability, particularly on the downstream voyage. The upper limit of length is determined by the towboat's ability to make a turn without sweeping the outside bank.

2. Breadth is limited by the same considerations as length but less critically. It is related to the width of individual units and to the number of units placed abreast. Generally the number of units is limited to three (3) abreast because four (4) abreast does not allow a symmetrical location of towboat and five (5) is too wide for navigation. Apart from those sections of the river where the navigable channel is limited to 200 feet or so, the breadth is limited by the relationship to the total cross section of the river flow.

3. Draft. Of the three dimensions, draft is the most important in relation to payload. Obviously it is limited by the depth of water available but less obviously by the speed of travel and other considerations discussed below.

Shallow Water and Canal Effects

It is a common misconception that water, enough to float a vessel, is sufficient for its operation. This is far from

Shallow Water and Canal Effects (Continued)

true. Shallow water affects progress in two ways:-

(a) The resistance of a vessel increases radically with decrease in water depth. This effect is related to speed versus $\sqrt{Wd}$; for instance, a vessel drawing 4 feet is affected above 10 mph in a water depth of 16 feet. The same vessel is affected above 3 mph when water depth is 9 feet.

(b) There is a critical velocity for a wave in shallow water regardless of wave length. The resistance of a vessel reaches a maximum at this speed and decreases rapidly above it. At this critical speed, the bow and stern wave increases and frequently the towboat ships water over the bow.

(c) The resistance increases rapidly when the ratio of cross section of vessel becomes large in relation to cross section of canal or river. This is less important downstream than it is in still water or upstream.

At a certain depth of water, there is a critical velocity for a towboat or barge beyond which the bow drops suddenly into contact with bottom. This phenomena occurs at depths and ratios of cross section which are surprisingly large. For instance, typical barges at 5 foot draft have a critical velocity of 7 mph in 8 feet of water when the effective canal width is in order of 300 feet.

This critical speed relates to an increase of velocity under and around the vessel which, developing an apparent suction, draws the vessel down at bow where velocity is greatest. As soon as the bow drops, the velocity must increase and the suction peaks rapidly so that the bow will drag bottom until the speed is reduced.

Shallow Water and Canal Effects (Continued)

(c) (Continued)

It is relatively simple to determine this phenomena mathematically for an ideal canal but in actual river navigation the results are modified by the variations in current velocity and the quality of bottom.

Size of Flotillas

The following broad considerations enter into the choice of barge and flotilla size:-

1. Relation of barge dimensions to parcel size for particular destination.

2. Capabilities of towboat.

3. Overall dimensions of flotilla in relation to navigational hazards.

4. Dimensions of prefabricated barge sections related to shipping facilities.

The size of individual barges has increased rapidly in recent years from 500 tons through 1000 tons and finally to 1500 tons per unit, all rated at about 5'-0" draft.

In the course of this development, the size of a typical six (6) barge flotilla has changed about 40% in width, from 120 feet to 168 feet; and 60% in length, from 300 feet to 500 feet, but the carrying capacity has increased threefold. The question arises, "How far can one go in width and length?"

Presumably the 500 x 168 ft. barge flotilla has been accepted by the operating personnel. Might they accept, say, 600 ft. x 180 ft.? If they do, the affect on total cargo at 5 foot draft is an increase of 30%. For the time being, we may consider this probable.

Size of Flotillas (Continued)

At the present the barges are rated at 5 foot draft, although there are times when greater and lesser drafts are permitted or required. Operations are underway at the Sans Sault to increase water depth and it seems reasonable to expect that an increased operating draft is possible in future. If we assume that, as a first phase, an increase to 6'-0" is possible, the corresponding increase in dead-weight is in order of 25%.

It is possible then to contemplate an increase of 60% in capacity, over the largest existing flotilla, from 9000 tons to 14,500 tons.

Barge Speed and Resistance

Before leaving the subject of increasing barge flotilla capacity, we propose to consider, briefly, the subject of barge speed and resistance as it relates to increased annual through-put.

One of the first thoughts which comes to mind on subject of resistance is the possibility of an integrated tow such as is now the common mode on the Mississippi.

The integrated tow forms virtually a single vessel by combining a series of box shaped middle units with a series of forward and aft rake units. The elimination of the eddy making points where rake ends and bilge radii meet, together with the reduction in wetted surface, reduces the resistance in order of 20%. Attractive as such a saving appears, it may not be practicable of achievement.

Apart from the non-technical consideration that there is a large fleet of existing barge units, we must consider;

(a) Maximum speed loaded downstream is seldom exercised. The combined speed of current and tow is frequently too high for safe navigation and full power is not employed except in straight stretches.

Barge Speed and Resistance (Continued)

(b) In course of upstream voyages, flotillas must be broken up in order to relay at fast water.

(c) In case of bad weather, barges must be handled across Great Slave Lake on a towline.

(d) Towline operation on the Arctic is becoming an important consideration.

At the present time these considerations appear to rule out the possibility of an integrated tow for the immediate future and we shall consider other possibilities.

The average river barge form employs long rakes which, with their shallow draft, ensures that bare hull resistance of barges is not likely to be improved significantly and we are left with the possibility of reducing skeg drag.

It has been past practice to use a pair of double plate skegs of simple form placed at an angle of about 8^{o} to centre-line. Possibly this is a good method but our experience with coastal barges leads us to believe that the minor cost of an investigation of the effect of skeg drag on the flotilla resistance loaded and light would pay off if only a small improvement were obtained.

To summarize the foregoing, it is evident that a substantial increase in cargo throughput is possible by increasing size of flotilla and by increasing draft. Some increase may be possible by refinements in barge design.

Larger Units or More Units?

In foregoing paragraphs we have indicated that it is possible to contemplate an increase of cargo capacity on one flotilla. The question remains as to whether such a unit may be efficiently propelled or whether the size should be limited to correspond to the optimum propulsion.

The resolution of this question requires an economic analysis which is outside the scope of this paper. In succeeding pages we shall examine the ramifications of higher power requirements.

Section III

TOWBOAT DESIGN AS IT RELATES TO INCREASING CARGO THROUGHPUT

General

In the previous section we discussed the possible trend to larger and heavier barge flotillas. We now deal with the motive power with which to propel such objects.

The design of shallow draft vessels is a subject which is not widely covered in the literature. A certain amount of information is available concerning Mississippi towboats but these are relatively deep draft vessels in relation to the requirements for the Mackenzie. Six (6) to eight (8) foot draft is common on the former whilst four (4) feet is deep for the latter. Papers have been published by A.R. Mitchell[1], a designer with the Yarrow organization in Britain, and W.P. Walker[2] with Wm. Denny of Dumbarton. These have been the principal source of information concerning tunnel stern boats. Some examples of shallow draft vessels appear in a Netherlands reference work[3] and that is about the sum total of available data apart from the experience of practical operators.

The development of the screw propelled tunnel stern vessel stemmed from a desire to utilize the more efficient compound and triple expansion reciprocating engine rather than the simple but fuel gobbling atmospheric exhausting simple steam engine so perfectly adapted to turning a paddle wheel.

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(1) "Tank Tests with Towboats and Barges in Deep and Shallow Water", Institute of Engineers & Shipbuilders in Scotland, A.R. Mitchell, 1950.

(2) "Tunnel Type Vessels", Institute of Engineers & Shipbuilders in Scotland, W.P. Walker, 1953.

(3) "Small Seagoing Craft and Vessels for Inland Navigation", A. Roorda, 1957.

General (Continued)

The early screw steamers such as those used on the Nile and on the "Road to Mandalay" (Irrawaddy) were very efficient. The hulls were usually fabricated in Britain and assembled piece by piece at the destination. They were carefully designed for lightness. They used large slow turning propellers and gave screw propulsion a reputation for being more efficient than the stern wheel.

The advent of the diesel engine was a further incentive to depart from the stern wheel. Although several examples of diesel electric and gear driven paddles were built in the 1920's, the mechanical and weight problems led to the almost universal adoption of the screw propeller.

Along with this transition from paddle to screw came the demand for more powerful vessels to push barges and thereafter great demands were placed upon the propulsion system to the detriment of efficiency.

Principles of Tunnel Stern Propulsion

For the benefit of those not familiar with the concept of a tunnel stern vessel, let us review the basic principles.

A tunnel is a duct in the bottom of a vessel which permits use of a propeller relatively large in relation to the draft. Because the hull surrounding the tunnel prevents the access of air, the propeller behaves like a pump, drives out the air and thereafter operates in solid water. The upper tip of the propeller may be as much as half the diameter above the static waterline although general practice limits this distance to about one-third diameter. Fig. 2 illustrates a conventional twin screw tunnel arrangement.

The propeller is a device which accelerates a stream of water thereby producing an axial thrust which is transmitted along the propeller shaft to a thrust bearing to propel the vessel. This thrust must be generated by the projected area of the propeller blades.

Principles of Tunnel Stern Propulsion (Continued)

This force multiplied by the speed of the propeller through the water expresses the H.P. usefully employed. The ratio of this power to the power applied at the shaft expresses the efficiency of the propeller.

Propeller efficiency decreases as loading increases and as speed through the water decreases. The load relates to the area of propeller. In a shallow draft vessel, the propeller diameter is severely limited by the draft available consequently increasing power results in a severe loss of efficiency.

Trend Toward High Propeller Loading and Low Efficiency

If it were possible to limit the power on shallow draft propellers to that shown opposite vessel No. 2 in Table I, the pull per H.P. at towing speeds would be in order of 22 lbs. Table I indicates a vessel operating at 4.5 times the propeller loading of towboat No. 2, therefore it must be anticipated that the thrust per H.P. must be in order of 11 to 12 lbs. per H.P. The propeller efficiency of towboat No. 2 is in order of 35% whereas No. 6 only converts 17% of the power applied into propeller thrust.

These figures are of little interest to the operator. He wants thrust to get barges upstream and he knows by experience that an increase of power gets results. However the very high propeller loadings bring on other problems. Wasted power requires flotation for the engine and the fuel to drive it thereby increasing the size and cost of the towboat. The high loadings of propellers also bring on the bothersome results of propeller cavitation.

Cavitation Phenomena

As the load on a propeller blade increases, it enters into a phenomenon similar to stall of an aero wing. The flow which under normal conditions passes smoothly past the blade section becomes turbulent on the upper surface and, if the pressure is low enough, forms cavities containing only gas at low pressure. These cavities form and collapse producing violent shocks which are transmitted through the water to the

Cavitation Phenomena (Continued)

hull thereby causing great noise and vibration. Frequently this produces fatigue in the metal of the tunnel adjacent to the screw disc and it cracks. In some cases large areas become completely detached. This phenomenon has been generally accepted as a necessary evil in the quest for more power. Tunnel structure has been made thicker and stronger to resist the forces with a corresponding increased weight.

Because the propeller diameter is limited and it is impracticable to raise the propeller disc area ratio beyond, say, 85%, it becomes necessary to raise the rotative speed of propeller in order to absorb the power. (Power varies in proportion to cube of R.P.M.) High rotative speed produces two other unfavourable results; (a) a loss of efficiency due to excessive drag on blade foil, and (b) a cavitation phenomenon at blade tips. If the tip velocity remains below a limit in order of 110 to 120 ft./sec., the cavitation effects will be negligible but higher speeds invariably result in severe noise and high frequency vibration.

A good deal of attention has been devoted to controlling the results of these cavitation phenomena which, it must be said, have not always been recognized for what they are. It has been found, for instance, that increasing the clearance between propeller and tunnel surface reduces the severity of the effects.

Tunnel Forms

Because propeller phenomenon are generally not well understood, a great deal of attention has been focused on the hull configuration related to the propeller and particularly to the form of tunnels. A trip around the winterized fleet of tunnel boats will expose one to an amazing variety of full scale experiments on form of tunnels. Some of these have been determined on basis of simplicity of construction, as for instance the rectangular cross section related to the simplest form of wood construction, the fundamental D form tunnel, the tunnel with rounded corners at the tunnel/hull intersection, the more refined tunnel in which the outer portion is raised to improve the entry from the side, and all the freak and crank varieties. One of the weirdest of the latter is one in which the fore and aft axis of the tunnel was bent towards the ship's side on the assumption that the limited clearance from the

Tunnel Forms (Continued)

bottom would increase the demand from the side. The assumption is true but this tunnel terminated inboard of the bilge and the water was forced to enter by the same limited access as before. Figs. 1, 2 and 3 illustrate a few of these forms.

Water Inflow to Tunnel Propellers

It was eventually demonstrated that improved performance was related to the area avilable to flow from ahead and from side and to the steepness of the angle of directional change ahead and astern of screw. The form of tunnel illustrated by Fig. 2 has been an excellent solution for tunnel vessels of moderate power, but the needs of the present dictate a new approach. A look at the flow requirements of a high powered vessel illustrate vividly the nature of the problem. Consider two propellers of 60" diameter times 4'-0" pitch turning 10 R.P.S. The combined flow (without slip) within the compass of the 5'-0" disc above amounts to 44 tons per second. Such a rate produces a very significant pressure gradient under the stern of a vessel and it is not difficult to understand the need for greater amounts of bottom clearance and for alternate routes for water flow.

From the foregoing, it is apparent that the problem of increasing the thrust necessary to propel larger tows involves two principal problems;

1. Excessive unit loading of propellers and corresponding low efficiencies.

2. Inadequate inflow into propellers.

The measures normally taken to reduce the unit loading of propellers in twin screw arrangements, that is utilizing maximum practicable propeller diameter and area of blades, prove inadequate for the powers now necessary and we have turned to the seemingly obvious solution of adding more screws. It is rather odd that there has been a strong resistance to the use of more than two (2) screws. Probably this has arisen from the lack of success enjoyed by some three (3) screw vessels.

Water Inflow to Tunnel Propellers (Continued)

The technical reason for the poor performance of three (3) screw arrangements, i.e. resistance to inflow for the centre screw, need not apply to four (4) screws as the pairs virtually share a single tunnel.

The total effect of four (4) screws plus maximum area for influx is a serious loss of displacement and forward movement of the L.C.G. To counter this effect, we have provided a hydrofoil body immediately outboard of the screws. This gained a moderate amount of displacement located as far aft as possible and had two side benefits; (a) propeller protection, and (b) it produced a secondary wave cancelling the trough normally developed at the position ahead of the propeller.

Performance of Quadruple Screw Vessels

The quadruple screw and the hull form described above and illustrated by Fig. 4 was adopted for the M.V. "Arctic Circle No. 1" constructed in 1969 and utilizing four (4) 500 H.P. engines on 3'-3" draft. This was followed in 1970 by a smaller vessel, the M.V. "W.H. Horton", using four (4) 250 H.P. engines on only 28" draft.

No tank test data nor pull scale measurements are available for these vessels nor for any standard type tunnel towboats on the river, however, we have indicated in Table 2 thrust figures calculated on basis of theoretical propeller thrust less an arbitrary thrust deduction which may or may not be realistic.

In considering these figures, one should relate them to the corresponding draft. For instance, the performance of the "W.H. Horton" in terms of thrust/H.P. is actually inferior to the twin screw "Sans Sault" but one should realize that a "Sans Sault" at 28" draft could produce little better than half the 17,000 lbs. attributed to her 54" propellers.

Included in this table is a hypothetical vessel using four (4) 1800 H.P. engines on 4'-6" draft. Presumably this is the type of power that would be required to handle the super-flotilla visualized in Section I of this paper.

Design of the M.V. "Vic Ingraham"

The extreme low water conditions on the river during the fall of 1969 led Northern Transportation Co. Ltd. management to consider the construction of a towboat having power similar to that of the combination river and arctic boats built in 1969 but with considerably less draft. A target of 3'-6" was contemplated.

Basing our thinking on the experience with the "Arctic Circle No. 1", we proposed a quadruple screw arrangement as a feasible way in which to attain the thrust necessary to equal or better the performance of the deeper draft boats.

The Norther Transportation officials were willing and anxious to explore any technology connected with propulsion or power plant and active consideration was given to possible benefits from controllable pitch propellers, gas turbine machinery, and Kort nozzle propulsion. The C.P. propeller was not recommended because a flexible range of R.P.M. could achieve the desired result of obtaining full power with light loads in upstream direction. The advantages of having propeller blades individually removable was held to be outweighed by the risk to propeller hub and hollow tailshaft.

Gas turbine propulsion was rejected for the present because of high initial cost and excessive fuel consumption. Any savings in weight due to lighter machinery would be offset by need to carry additional fuel.

Kort Nozzle Propulsion

The utilization of Kort nozzle propulsion was attractive. We had a background of involvement with many successful applications and it was apparent that the high loading of the shallow draft propellers and the low intake velocity were conditions under which the nozzle propeller could offer gains in thrust in order of 15 to 20% at operating speeds. Such propulsion systems are used in many European rivers and by all modern towboats on the Mississippi.

In order to utilize the standard concept of a Kort nozzle, the aft body of the towboat must be cut away as much as practicable to allow free circulation around the nozzle and minimum obstruction to the inflow of water. This arrangement is most vulnerable to

Kort Nozzle Propulsion (Continued)

damage by bottom contact. The illustration, Fig. 5, demonstrates this point. It is easy to visualize the leading edge of the nozzle contacting a rocky bottom or a large boulder with consequent serious damage. This, to us, was unacceptable and we began to explore alternatives.

The Propulsion System of the M.V. "Vic Ingraham"

Finally, our Assistant Naval Architect, Mr. Gruzling, proposed an arrangement which in its final form was adopted for the "Vic Ingraham". This form is illustrated in Fig. 6. It combines the aft bulb of the "Arctic Circle" with two closely related ducts which are integrated into the tunnel forming a well supported unit protected inboard and outboard by an extension of the hull.

The hull form was opened out ahead of the ducts in such a way that the velocity of inflow was first lowered and then rapidly accelerated into the duct entry. It was believed that this should produce a thrust augment similar to that of a Kort nozzle.

Tank Testing for "Vic Ingraham"

Because of the unusual nature of this arrangement, we were anxious to prove it by tank test and were fortunate in gaining the cooperation of Northern Transportation towards this end. In spite of close timing on the building program, we were able to complete tank testing at the Netherlands Ship Model Basin at Wageningen, during April 1970, without delaying construction.

In order to obtain some index of comparison between the duct system and the standard tunnel configuration, two series of testes were run; one with the ducts as designed, and one with the lower portion of the duct removed and the tunnel faired into a form similar to that of the "Arctic Circle No. 1".

The model was run behind a flotilla of barges at zero, 4, 8 and 12 mph and at zero speed astern. For the first tests the water depth corresponded to 33 feet on full scale and for the second to 8 feet. During each test the power input to the screws was varied in order to obtain a line plot of all measurements.

Tank Test Results

The results confirmed the expectation that the duct would produce a thrust augment over that of the open screw. Fig. 7 illustrates the extent of this augment which at zero speed exceeds that of open propeller system by 38%. It is useful to examine the source of this augment. The tank test measurements indicate a fairly constant total thrust of about 26 tons along the propeller shafts but the line pull at zero speed exceeds the propeller thrust by 65%! The thrust on the ducted propeller is only 75% of that on the open propeller and correspondingly the torque necessary to turn the ducted propeller at a given R.P.M. is less by 33%. Obviously the unit loading on the ducted propeller is much reduced compared with that on the open screw.

This fact, together with the remarkable difference in the appearance of the propeller wash astern of the vessel, led us to believe that the duct system would operate without the heavy cavitation and consequent vibration of the heretofore standard arrangement. Fig. 8 illustrates the turbulent nature of the wash behind the open screw. No similar illustration is available for the ducted arrangement because there was insufficient contrast to register on film.

Preliminary Trials of M.V. "Vic Ingraham"

It was hoped that an opportunity would avail to tow loaded barges over a measured course whilst measurements of line pull and engine performance was taken. Unfortunately, this was not feasible this year because the vessel was not completed until the very end of the navigation season.

The vessel left her building site at Bellrock on October 9, 1970 and proceeded down the Slave River. It was noted with some satisfaction that this very shallow vessel was directionally stable and yet responsive to helm.

The absence of vibration and noise was in such contrast to the usual experience of the Master and Mate that they expressed doubts about the speed. Subsequently, observations for the time to cover charted distances indicated a rather good speed of 15 mph in the shallow river and 16 mph in deeper water of Great Slave Lake.

Bollard Pull Measurements

A bollard pull trial was carried out under restricted conditions of channel and depth at Hay River. These results were in line with those of the tank tests in 8 foot water depth.

Service Trials

Following the bollard pull measurements, a trial run was undertaken under service conditions pushing four (4) barges upstream at Providence Rapids.

The operators were satisfied that the pushing performance would enable them to handle six (6) barges rather than the usual four (4).

It was not possible to conduct further trials and we must await next season's operation to determine the performance downstream with a heavy tow. In particular, we shall be anxious to know whether or not the nozzle structure serves as a protection to the screws.

Conclusions

The performance of the quadruple screw tunnel towboats constructed in 1969 and 1970 was indicative of a major breakthrough in navigation on the Mackenzie. We are optimistic that the performance of the "Vic Ingraham" will be a further step forward. It seems now practicable to operate tows in order of 9000 tons potential deadweight and further extensions are possible.

Whether or not this should be the direction of development remains to be seen. If the river should be sufficiently improved to permit operation at deeper drafts, the trend possibly will be to large units, however, we shall anticipate that in the future a closer scrutiny of system economics will be applied towards establishing optimum flotilla size and motive power.

* * *

TABLE 1

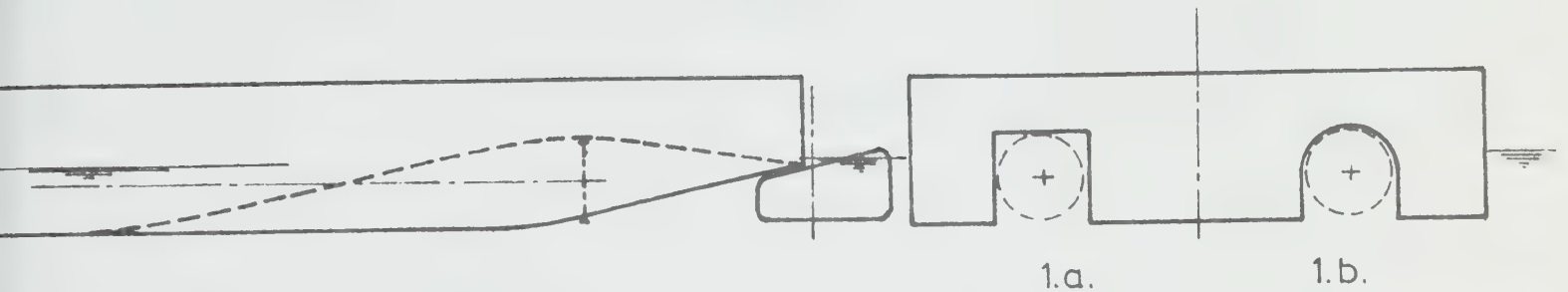
Vessel	Year Built	Power	RPM	Prop. Dia. in.	Disc. Area ft.^{2}	BHP / D.A.	Tip Speed ft./sec.
1	1944	2 x 115	600	37	7.5	15.3	97
2	1965	2 x 380	450	54	15.9	23.8	106
3	1946	2 x 500	500	54	15.9	31.5	118
4	1947	2 x 400	700	40	8.6	46.5	122
5	1959	2 x 1440	720	54	15.9	90	170
6	1969	2 x 2150	600	60	19.6	107	157

TABLE 2

Vessel	Mean Draft	Power SHP	RPM	Prop. Dia.	Calc. Thrust at 8 mph	Thrust per SHP
Sans Sault	3'-4"	2 x 380	450	54	17,000	22
Arctic Circle	3'-2"	4 x 465	600	42	32,000	17.3
W.H. Horton	2'-4"	4 x 230	667	34	18,400	20
No. 5	5'-6"	2 x 1400	720	54	33,000	11.8
No. 6	4'-6"	2 x 2100	600	60	50,000	11.6
Vic Ingraham	3'-6"	4 x 1070	500	56	64,500 (a)	15
'X'	4'-6"	4 x 1800	420	67	108,000	15

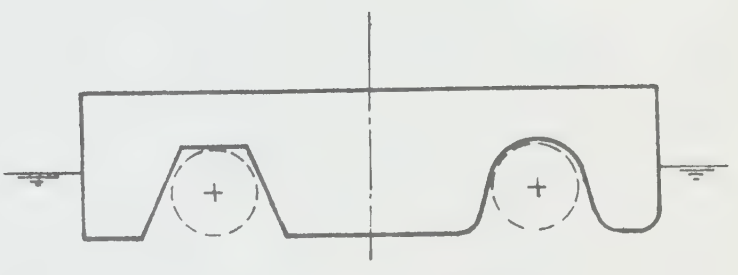
(a) Based on tank test results.

FORMS OF TUNNEL



1.a. 1.b.

FIG.1. SIMPLE TUNNEL FORM



1.c. 1.d.

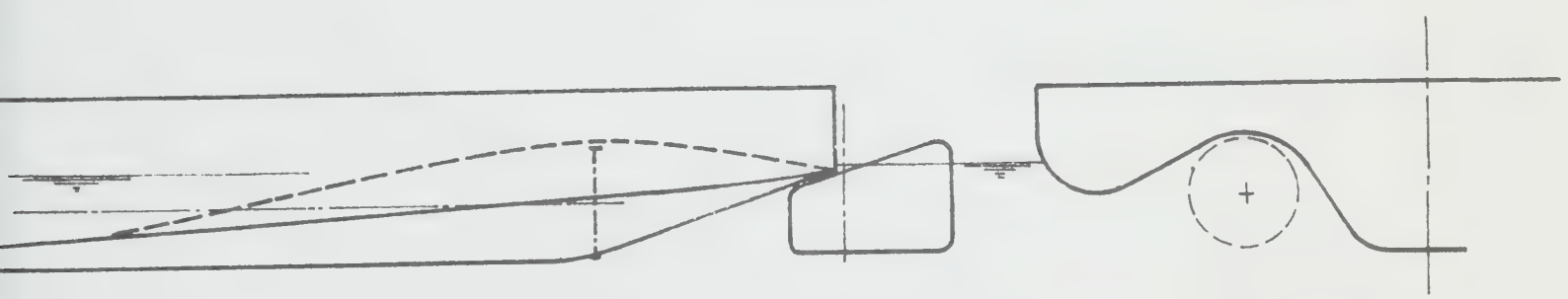


FIG.2.BASIC MODERN TUNNEL

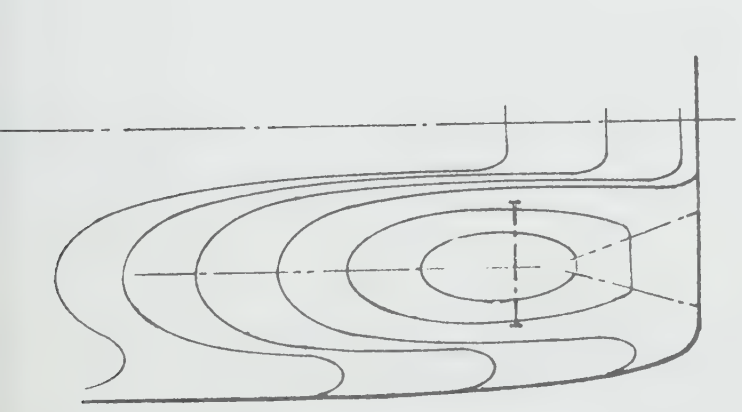


FIG.3.a. CONVENTIONAL TUNNEL WITH AXIS PARALLEL TO C.L.

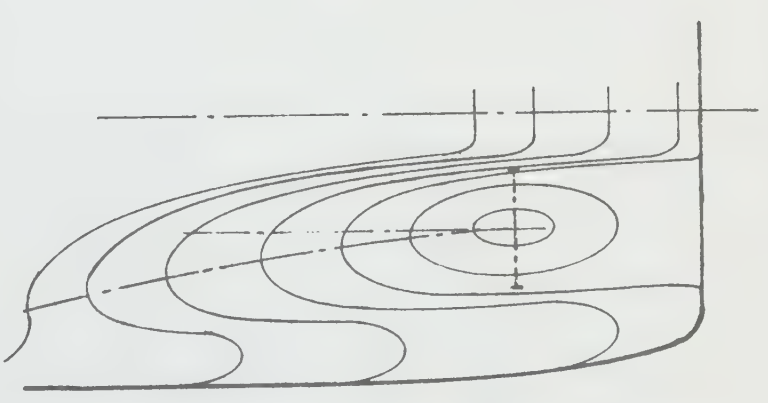


FIG.3.b. UNUSUAL TUNNEL WITH AXIS SKEWED

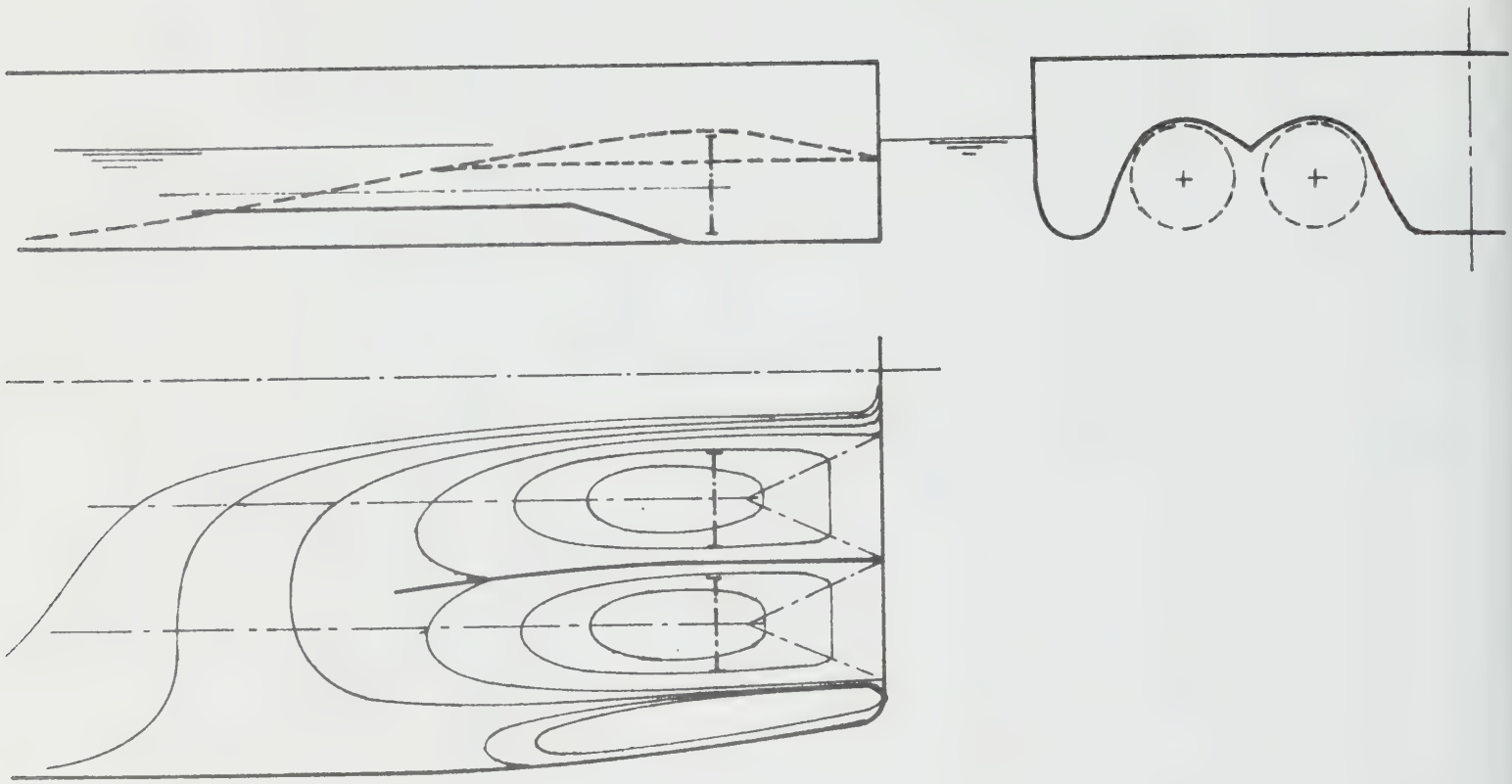


FIG.4 M.V. "ARTIC CIRCLE"

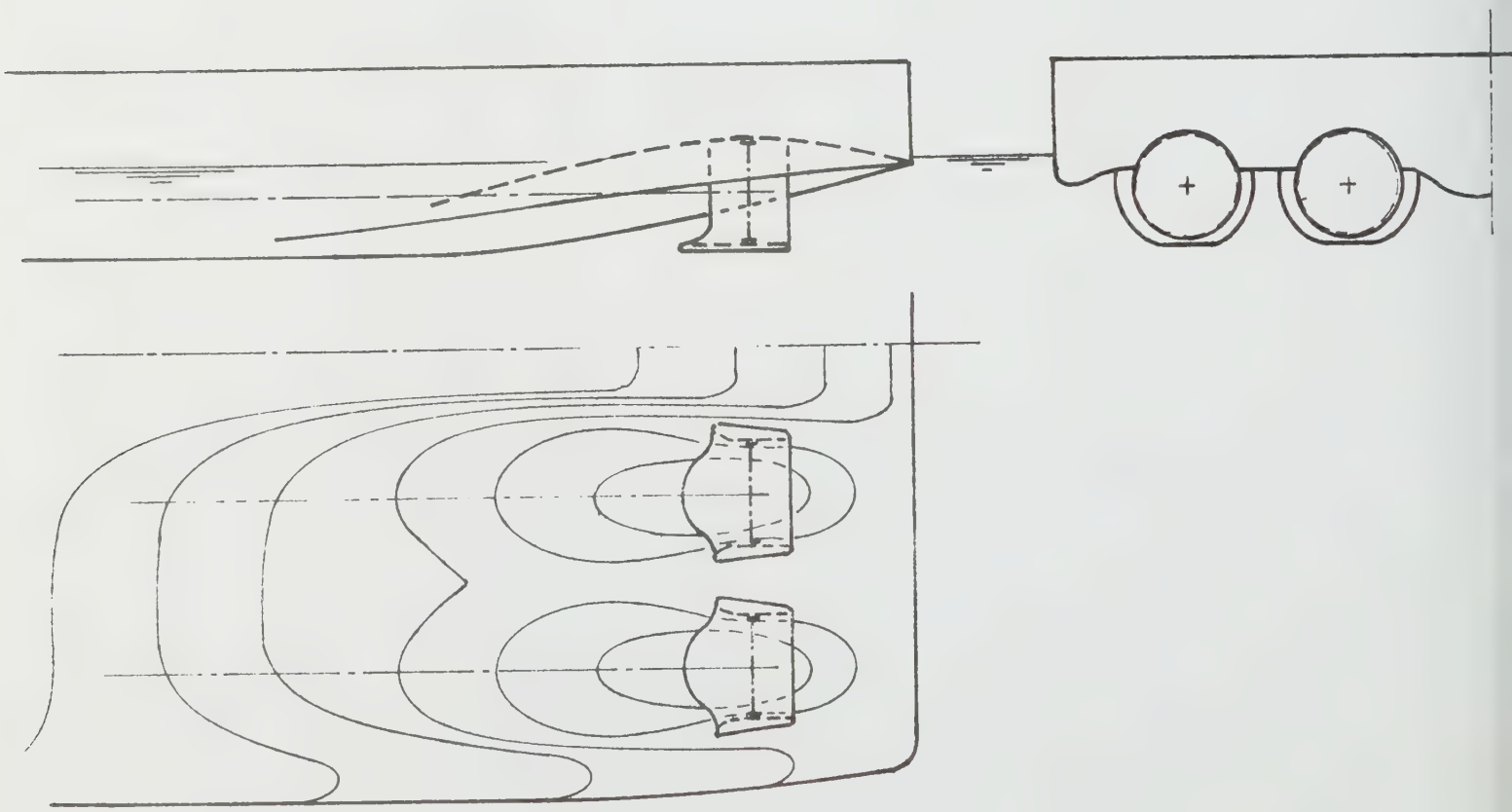


FIG. 5. KORT NOZZLE TUG

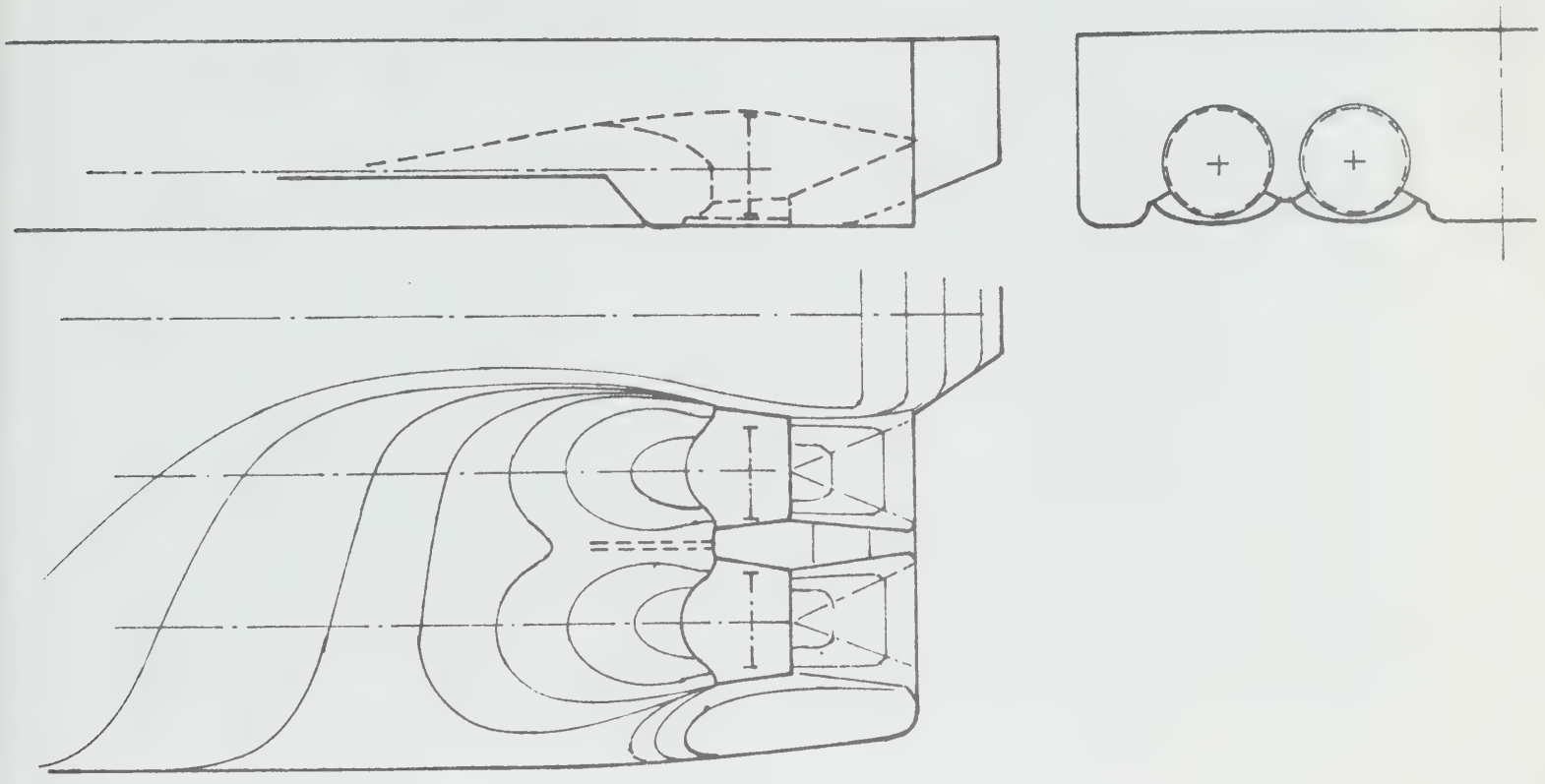


FIG.6. M.V."VIC INGRAHAM"

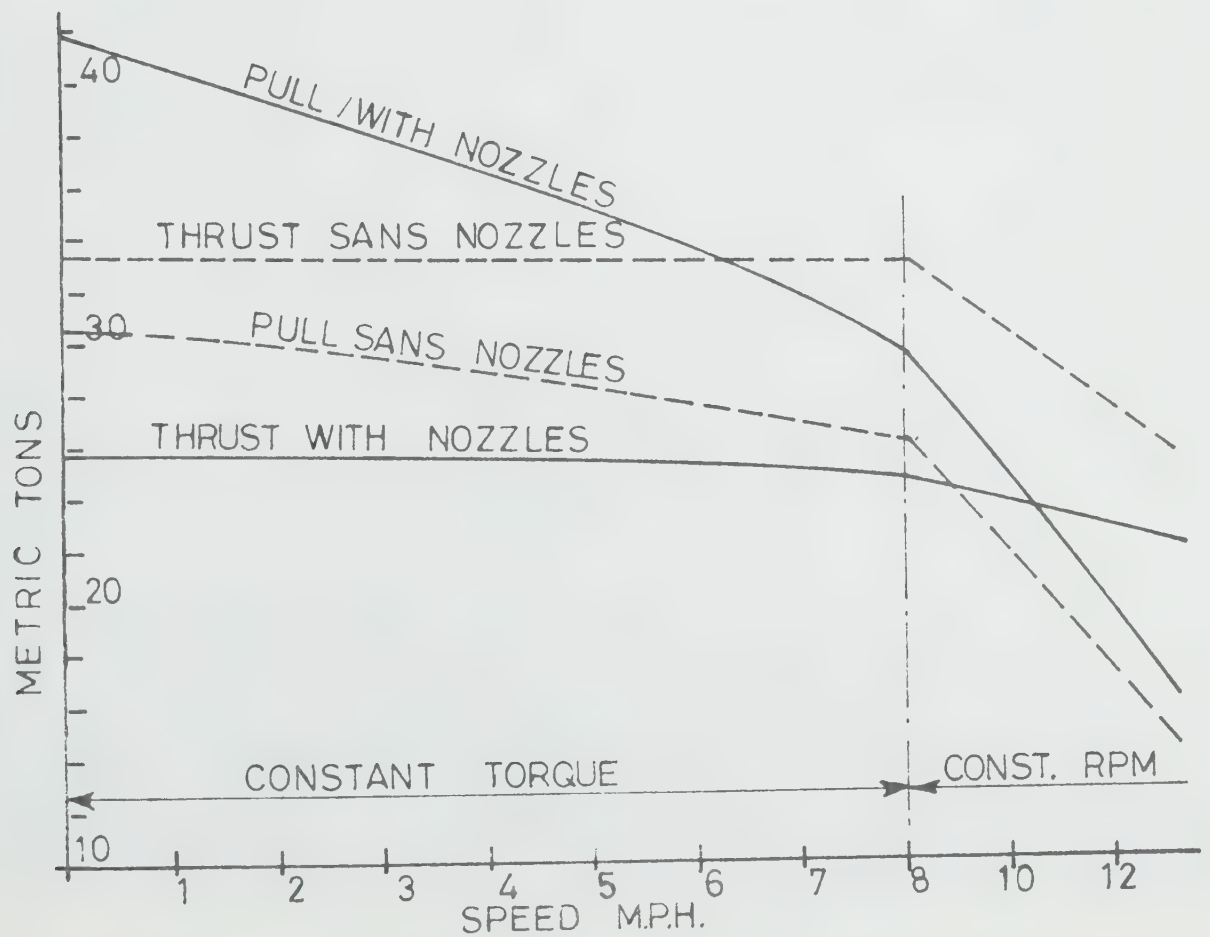
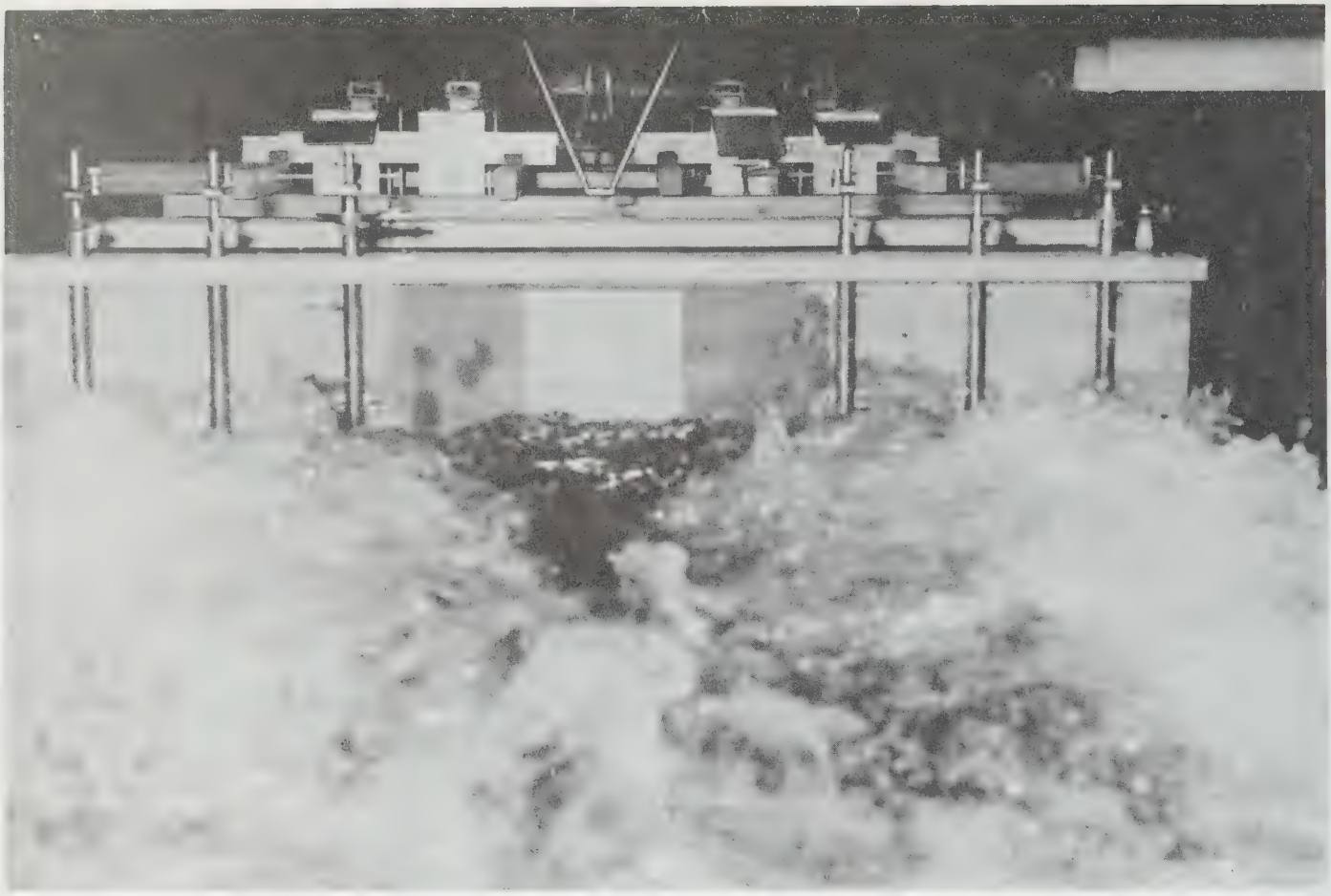
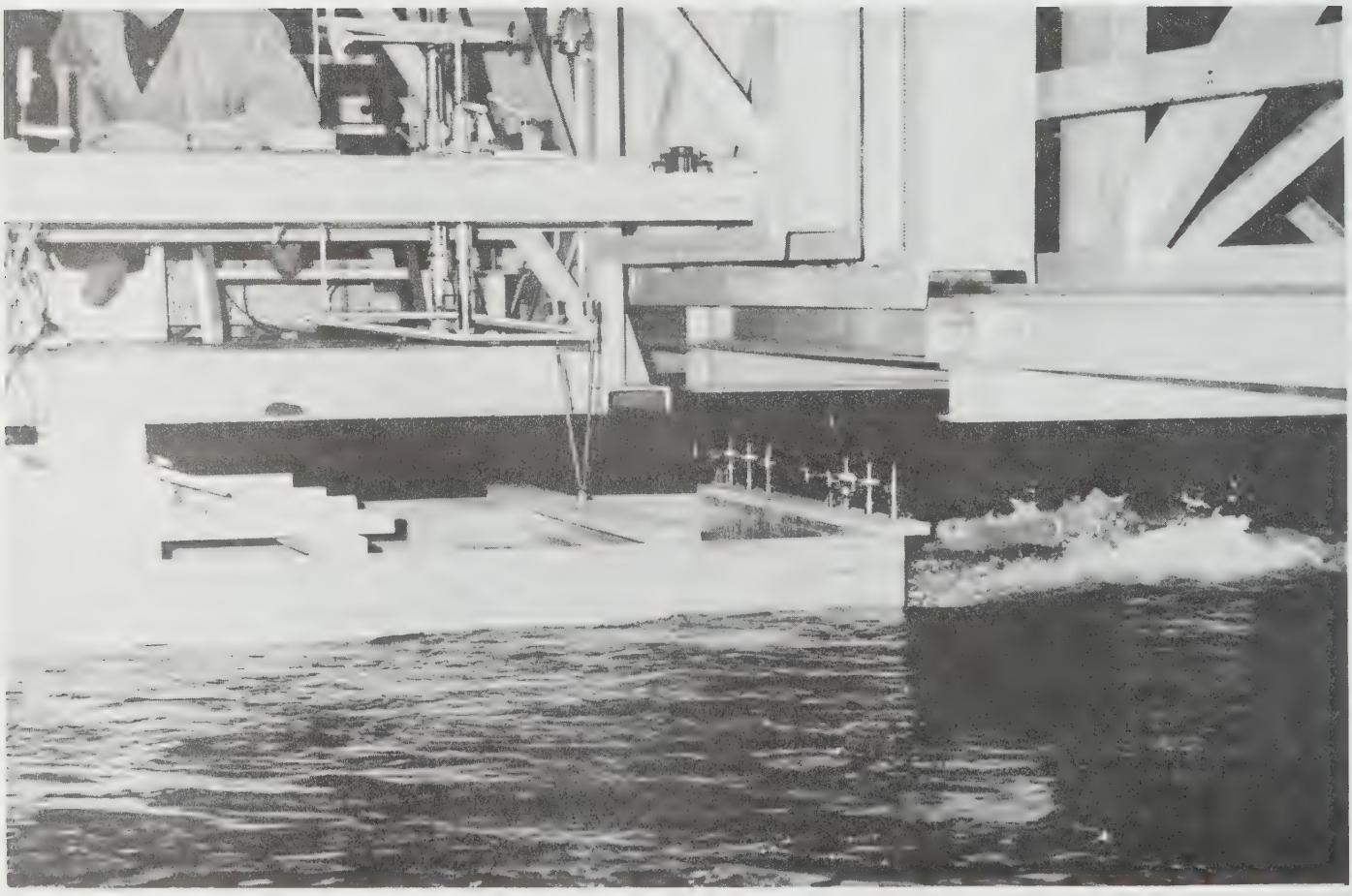


FIG. 7.





"THE ROLE OF THE MACKENZIE RIVER WATERWAY IN OIL EXPLORATION"

BY:
J.C. Underhill, Corporate Frontier Coordinator, Imperial Oil Ltd

It is indeed an honour and a privilege to be given the opportunity to participate in this panel discussion on Western Water Transportation. The Mackenzie River has developed over the years into the Highway to the western Arctic. Population concentrations and community development are along its banks and have not spread any great distance from the river and its navigatable tributaries.

This paper will deal with oil industry use of the Mackenzie River, possible future requirements and suggested means of improving navigation efficiencies. I recognize there are many persons in attendance who are very familiar with the Mackenzie River and the methods at moving goods and materials. However, I have gauged my remarks to those less familiar and therefore hope the experienced will bear with me.

For this presentation the oil industry requirements have been separated out to the degree possible. Tonnages mentioned will not take into account indirect requirements arising from the increased activity in any particular area.

For the oil industry, as for most other industries operating north of 60, the Mackenzie River is the main supply route. The Mackenzie River bisects the northern extension of the western Canada sedimentary basin as shown on Figure 1. It is sedimentary rocks that generate and trap oil and gas. The northern portion of this basin contains thick sediments, in places more than 20,000 feet thick, with large structures many of which have not seen the drill. Without this river and its barging system for moving goods, oil exploration would probably be only beginning or at best be at a much lower level. Oil operating areas served by the river are indicated by the heavy dash outline which extends on the north from Prudhoe Bay east to Banks Island and the Parry Peninsula. In general, supplies for Arctic islands oil exploration are moved in by sea through the eastern seaway with very little moving from the Mackenzie River further than Banks Island.

For the area north of Norman Wells the industry moves the bulk of its equipment and supplies down the river in the summer to staging areas, along the river or on the coast, for later movement after freeze-up to specific sites by conventional truck transport methods. To the south of Norman Wells part of equipment and supplies are moved in this manner with the balance being moved directly to the work sites over winter roads.

The average cost of shipping materials from Edmonton to Inuvik, through a combination of truck or rail and barging, is approximately $100.00 per ton. Much work has been done investigating the economics of various alternative transportation methods. In general, the economics favor the water route. However, special circumstances as to locations, equipment, standby charges or handling costs could favor an all-truck movement along the winter road from Fort Simpson at an approximate cost of $200 - $300 per ton to Inuvik or even a combination of truck and Hercules Air Transport at a cost of approximately $500 per ton. The use of the more expensive air transport usually indicates planning changes or emergencies.

This past navigation season the oil industry shipped approximately 150,000 tons down the river through Northern Transportation and Kaps Transport. On the basis of $100.00 per ton to Inuvik, the industry transportation bill for equipment movements and supplies to major stockpile areas totals between $10,000,000 and $15,000,000.

Navigation out of Hay River begins in early June and finishes about mid-September. The Mackenzie River has good channel depths with the exception of four areas which limit the draft of vessels. During the high water period, from early June to mid-July, vessels operate with drafts of over six feet. Nearly 65% of the total tonnage is moved during this period. Individual tows carry more than 6,000 tons and make the return trip from Hay River to Tuktoyaktuk in approximately 16 days. Later in the season a vessel's draft is limited by low water to three or four feet, reducing loads to approximately 3,000 tons. As well, barges have to be shuttled through the shallow areas nearly doubling the return trip travel time.

The shipper often creates many problems and a natural tendency is to blame the carrier. Late arrival of shipments at Hay River, poor packaging, inadequate item identification,

or a failure to determine priorities can create havoc with a shipping schedule. As well, poor docking facilities and small storage areas at the shipper's remote location can tie up equipment needlessly.

For today's volumes, barging equipment and facilities are good. Modern steel boats and barges have replaced the old wooden equipment. The present tugs have up to 45 hundred horsepower and single barges are capable of handling up to 2,000 tons during high water. Expansion is taking place to handle a moderate tonnage growth. However, if there is a sudden and large increase in tonnage, such as may be anticipated with a major oil development program and a proposed pipeline system, the facilities would not meet the requirements.

What might be the magnitude of oil industry transportation requirements in the next few years? At a transportation seminar, sponsored by the Arctic Institute of North America in March, 1969, I had forecast approximate oil industry tonnages for the exploration phase north of Norman Wells. These estimates excluded the Arctic islands, Prudhoe Bay and did not make any allowances for oil development requirements. Today, after some encouragement, an update might be interesting. Shown on Figure 2 are the 1969 estimates and the present estimates for the exploration phase. Present estimates increase from the 150,000 tons shipped in 1970 to 210,000 tons in 1971 to a level of 275,000 tons in 1975. Exploratory drilling activity is now estimated to increase from 23 wells in 1970 to about 30 wells in 1971 to about a 60-well level by 1975. The difference between these two estimates reflects an increased enthusiasm for northern prospects, possibly spurred on by the flow of oil from Atkinson Point this past winter.

You will notice in the forecast that more wells will be drilled in later years with only slightly increased tonnage requirements. Supply tonnages have been gradually reduced as drilling rigs will remain in the north. Also, it is assumed that special mud weighting materials and casing strings not used one year will be stockpiled for the longer period,thereby reducing requirements.

Assuming a giant oil discovery with the necessary high per well deliverability might be made say in early 1972, then additional development drilling would be done in 1973,

requiring supplies of about 75,000 tons for 20 wells, increasing to 125,000 tons for 60 wells in 1976 as indicated by the broken line on Figure 2. Along with development drilling would be a pipeline requiring large additional tonnages. Only the supplies and equipment for the portion of the line from Wrigley to Inuvik have been assumed to be moved on the river. Presumably, the materials for the northern most portion or for the possible extension to Prudhoe Bay would move in by sea. The southern section, north as far as Wrigley, might be supplied directly by a combination rail and truck due to handling problems. With these assumptions, possible transportation requirements for a pipeline have been estimated to be an additional 100,000 tons in 1973 and 1974, levelling off to 50,000 tons for 1975 and 1976, as shown by the dotted line on Figure 2. Should there be a need for two pipelines, one for oil and the other for gas, additional supply requirements would extend the period of large tonnage movements.

Putting all these requirements together portrays an increasing demand for river transportation which could total 450,000 to 500,000 tons by 1973 or 1974. This total is over three times that of 1970 and could be very conservative but does depend on the assumption of successful exploration. Without success but encouragement, requirements would likely follow the exploration curve. It should also be noted that increased refining or a crude topping plant could reduce the requirements for fuel presently moved from Hay River.

Over and above these requirements would be the escalated requirements to meet local community needs. These requirements would in some way follow the demand projected for the oil industry as there will be a marked increase in service demands and overall business levels in the major communities.

To meet these projected needs the Mackenzie River transportation facilities must be expanded. This can be done either through additional equipment, additional facilities, improved efficiency or a combination. It is not the responsibility of any one group to add this capacity.

I would strongly urge the transportation companies and the oil industry shipping companies to jointly study the entire transportation system. The aim should be to identify and take action to reduce or eliminate the most serious problems and

at the same time point out individual responsibilities. For the oil industry the incentive is great. The cost of drilling an exploratory well in the Mackenzie Delta can range from $700,000 to over $3,000,000 with an average cost about $1,000,000. Approximately two-thirds of this cost is for what we call logistics or the handling, stockpiling, and transportation of the rig, the materials necessary for the actual drilling of the well, and the extra materials necessary in case of difficulty being encountered or necessary to handle any possible production encountered. Of these logistic costs, one half or $330,000 per million dollars of expense is for transportation alone. The oil industry must continually endeavour to reduce the extremely high cost of operating in the Arctic region. Logistic costs are a prime target.

In order to portray the problems in a more specific manner an example can be cited. This past summer the producing department of Imperial Oil shipped approximately 23,000 tons of material down river for their northern exploration activities.

9,000 tons was bulk fuel.
6,000 tons was bagged and palletized goods.
3,000 tons was tubular goods handled piece by piece.
2,500 tons was miscellaneous palletized or skip boxed goods.
2,500 tons was miscellaneous goods with no packaging.

All the materials were transported from Edmonton to Hay River by truck or rail, then barged to the staging locations in the Mackenzie Delta. The goods were off-loaded at the staging areas over semi-permanent dock facilities by company, barge or contract employees with a limited number of specialized handling devices. The systems used have been developed over a great number of years and can probably be considered to be representative of industry handling methods. Each year the techniques are improved through experience. Even without an indepth study there are many areas where additional improvements are possible. To meet the forecast needs, major improvements must be made through the cooperation and coordination of industry, the transportation companies and government agencies.

Industry could reduce costs by

- developing a container shipping system which would

eliminate much handling and the requirement for palletizing goods. (Container shipments are being pioneered currently.)

- developing bulk materials handling methods, whereby cement and chemicals now shipped by bag on pallets could be shipped in silos, reducing handling.

- improved dock facilities and larger storage areas and improved handling equipment at the off-loading supply areas would reduce barge turnaround time.

- improved liaison with the carrier, whereby shipments would be in Hay River on time well packaged and well marked as to destination and priority, would again improve overall operations.

The transportation companies can

- continue to enlarge the tug and barge fleet.

- continue the updating and improvement of equipment.

- improve facilities on the barges for handling materials.

- improve scheduling of shipments.

- improve communications with shipping companies as to timing of loading and unloading would reduce costs. In remote areas companies cannot afford crews standing by waiting for shipments that don't arrive as planned or shipments that stretch out over the entire shipping season.

Government's role would be to

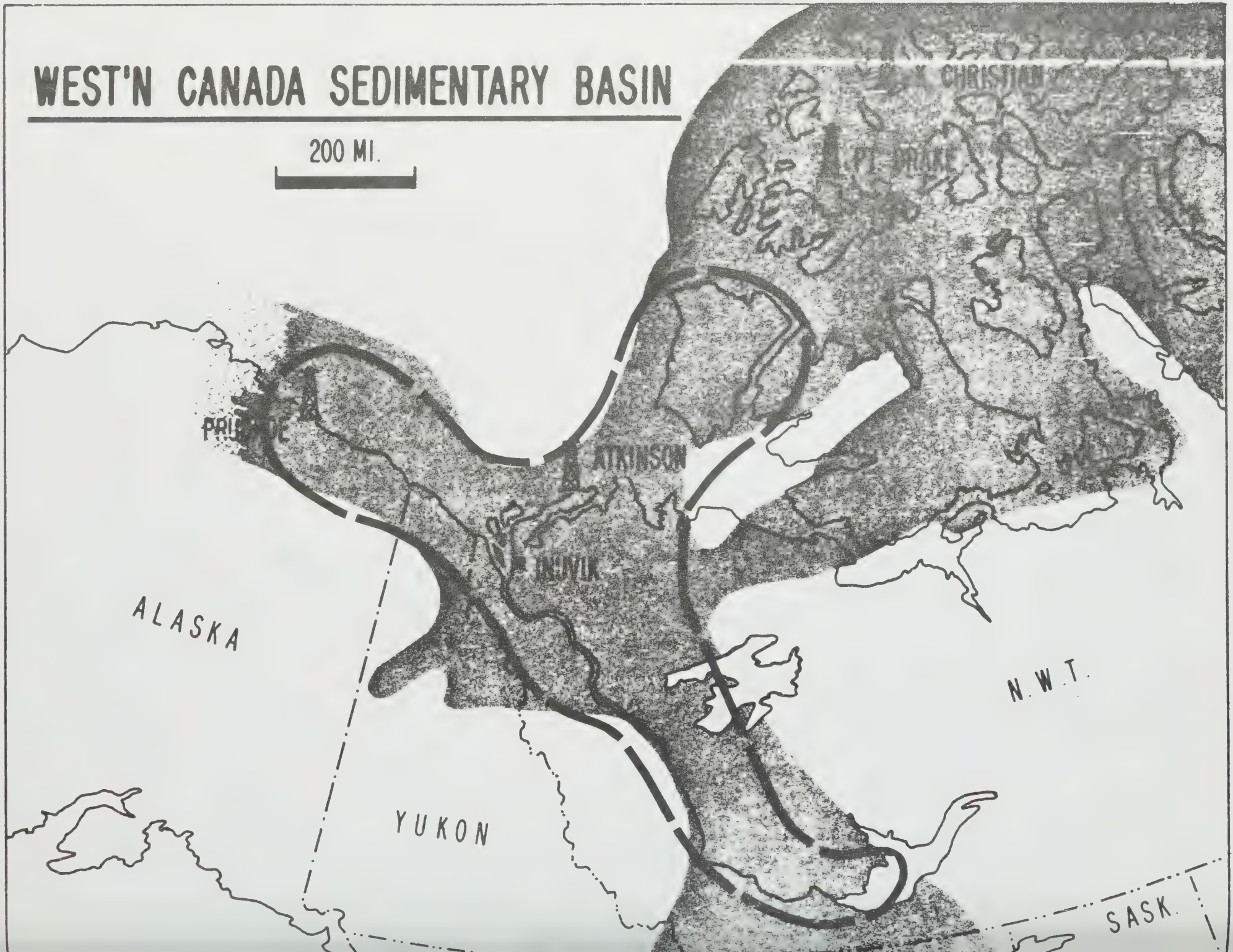
- improve the river itself by dredging the present shallows to allow maximum barge loading for the full season. The present work at San Sault should be extended and speeded up.

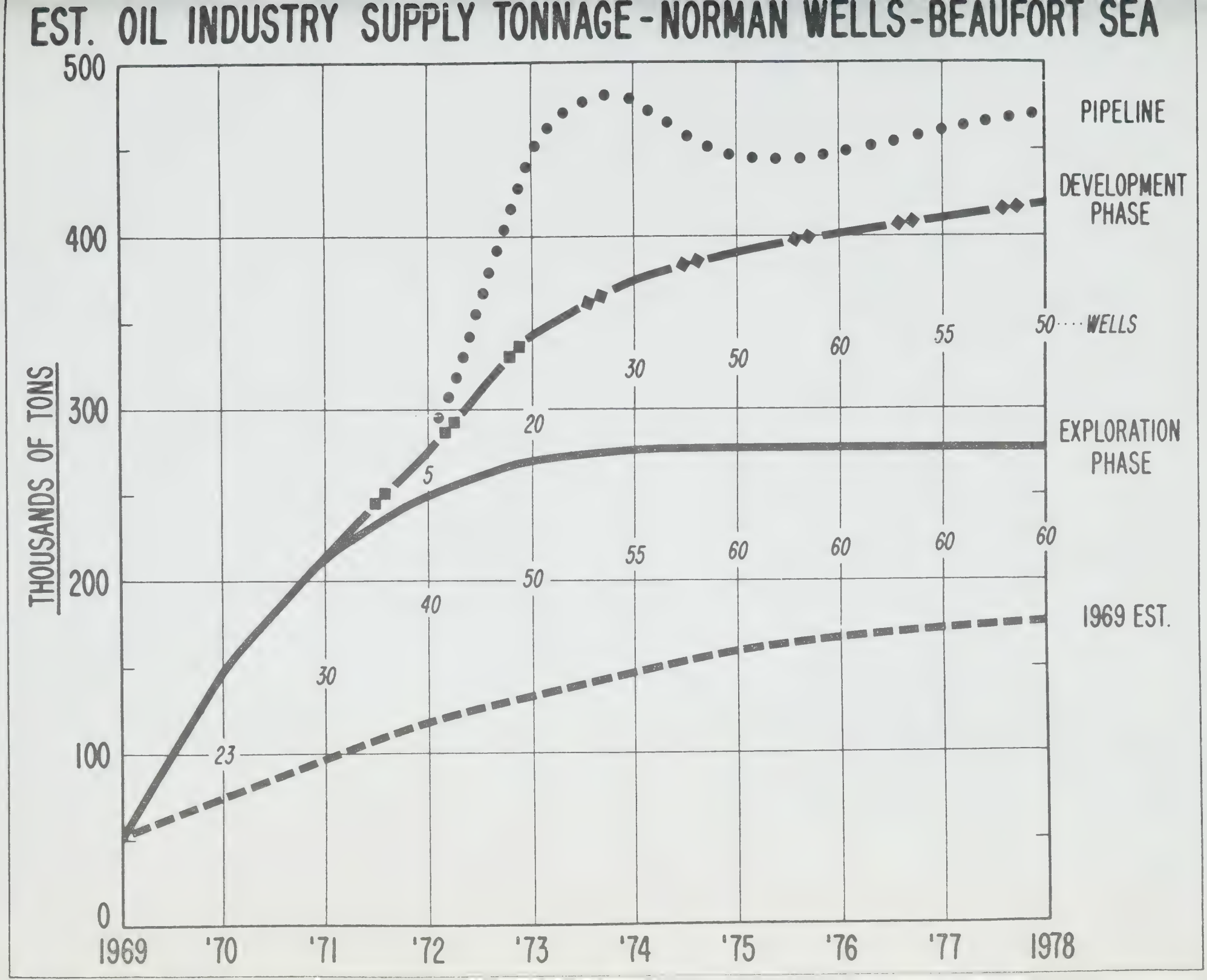
- improved navigation aids are required to allow river pilots to safely operate at night - even in shallow water conditions.

- improve port facilities at Hay River or possibly extend the present rail line to Fort Providence and develop a new major port. This would lengthen the navigation season into the period where the Mackenzie River is free of ice but the Great Slave Lake remains ice clogged.

The Mackenzie River system is the highway to the North. With success the oil industry will more than triple the present shipping demands. The present tug and barge facilities are capable of handling at least twice the tonnage now handled but require better river conditions and improved and more efficient handling facilities and techniques. The incentives will be there.

Should the oil industry predictions of the ultimate oil and gas potential of the North be realized, then transportation requirements would be many times of what I have forecast today. In this case not only would the river transportation requirements be expanded, but it would be necessary to develop a year-round road system to meet the needs. Our wish is that our forecast requirements will be as far short by 1972 as they were between 1969 and 1970.


WEST'N CANADA SEDIMENTARY BASIN
200 MI.
CHRISTIAN
ATKINSON
INUVIK
ALASKA
N.W.T.
YUKON
SASK.


EST. OIL INDUSTRY SUPPLY TONNAGE - NORMAN WELLS - BEAUFORT SEA
THOUSANDS OF TONS
500
400
300
200
100
0
1969
'70
'71
'72
'73
'74
'75
'76
'77
1978
PIPELINE
DEVELOPMENT PHASE
EXPLORATION PHASE
1969 EST.
WELLS
50
55
60
30
50
20
5
55
60
60
60
60
40
50
30
23

VOLUME 2

SECTION 5 - ICE INFORMATION, MARINE NAVIGATION AIDS AND TERMINAL FACILITIES

CHAIRMAN: W. J. Manning

PANELISTS: J. N. Ballinger

F. W. Benum

J. D. Garvie

O. C. S. Robertson

"Keep cool but do not freeze".

Don Jamieson - The
Mayonnaise approach.

MARINE NAVIGATIONAL AIDS AND TERMINAL FACILITIES

BY: J.N. BALLINGER
MINISTRY OF TRANSPORT

AIDS TO NAVIGATION

Environment

The development of marine transportation facilities in the Canadian Arctic has been slow, being severely restricted by the vastness of the area, the limited population and number of known or developed natural resources, but above all by the harshness of the climate. Although many questions have been asked in recent years about ice and its physical properties, whether in the north or elsewhere, they in great part remain unanswered and add in no small measure to the problems created by the harshness of the climate.

I think at this point it is worthwhile to quote directly from the revised wording proposed for "The Pilot of Arctic Canada", Volume I, the reference to navigation in Arctic waters which can be found there.

"Navigation in the waters of the Arctic regions, is beset with many problems not encountered in lower latitudes. These problems are created through various factors such as weather conditions, ice, charts, and lack of navigational aids.

Weather conditions, such as fog, ice and low cloud ceiling create a problem for the mariner, to determine his accurate position. These three adverse conditions are most prevalent during the months when ice permits navigation, therefore celestial observations to determine position, cannot be depended upon.

The present Arctic charts are largely based on aerial photography, although a program is underway to update these charts from controlled topographic and geodetic surveys, which now extend throughout the Arctic. There are, however, still some charts where discrepancies of some magnitude exist in the charted positions of islands relative to the adjacent coastline, also some discrepancies in distances between coastlines forming channels and sounds.

Some charts are lacking in topographic detail, such as prominent hills, mountains, glaciers etc. These features are essential for the navigator to fix or identify his position by means of radar or visually.

Soundings as shown on some charts, with the exceptions where harbours and landing places have been systematically sounded, are for the most part, a collation of individual ship track soundings, while accurate as to depths, may be misleading in their charted positions.

Aids to navigation, such as buoys, lights, fog signals and marine radio beacons, are almost non-existent, except in such well travelled routes as Hudson Strait, Hudson Bay, in the eastern Arctic and in certain areas off the mainland coast in the western Arctic.

The difficulties so far mentioned are not insurmountable if the navigator accepts the fact that unconventional methods are required to meet unconventional situations. It may be impossible to fix a ship's position geographically, but fixing relative to land masses, is usually possible and the fact the land mass itself is inaccurately fixed, is immaterial."

Past Aids Requirements

Generally speaking, there has been a large increase in the amount of traffic proceeding to the north since the war along with a corresponding increase in the amount of hydrographi and oceanographic information available to our chart makers. Some of this increase in traffic is related to the Dewline resupply and the entry into the western Arctic of additional shipping serving waters between the northern islands and the northern mainland shore. There has also been a considerable increase in marine traffic in the eastern Arctic related to exploration being carried out for new mineral resources. The search for oil and gas deposits in the mid and western Arctic has resulted in some additional traffic in these areas. In

the eastern Arctic the situation has been somewhat different and traffic has been coming into the Port of Churchill since the early 1930's, although it tapered off almost to nothing during the war years. Since the war it has steadily been picking up and in this area some aids to navigation were installed to provide for the needs of this traffic alone. However, in recent years there has been an increase in traffic in the Foxe Basin, in the Gulf of Boothia area and to some of the more northern outposts for resupply purposes.

With the increase in traffic above the Hudson Strait in the east and northward of the mainland in the western Arctic, increasing demands were placed upon the Ministry to provide aids to navigation which would give a positive radar response from some of the more important low lying land masses which, by themselves, would not provide the radar response necessary for positive location and identification. In the 1950's and 60's three-legged aluminum towers were erected in numerous locations throughout the north, surmounted by 36 in. aluminum radar reflectors at a height of approximately 30 ft. above the ground. They were in most cases, erected on poured-in-place concrete pedestals on the highest terrain in the area. There were instances where additional radar reflectors were erected on wooden towers instead of the aluminum as it was not always possible to obtain the aluminum towers on short notice prior to the service vessel sailing to the northern areas. In a few exceptional cases 4 in. tubular steel posts were used to support the same type of reflectors. In addition two Lunenberg lens type of radar reflector with a wide horizontal coverage were installed utilizing the 30 ft. three-legged aluminum towers in the Tukoyuktuk area on the southern extremity of the Beaufort Sea. Over the years since the installation of these devices many favourable reports have been received although we have wondered from time to time whether sufficient of them have been installed.

Additionally there have been day beacons erected to provide a visual aid on land masses which were required to be more prominently marked. These day beacons in general have been of the diamond shape with a fluorescent orange or red-orange paint applied to the shape itself. These have varied in size according to the location and distance from which they might be viewed.

To a very limited degree, lights have been installed in the northern areas in those locations where nighttime navigation is necessary during the early and late phases of the navigation season to complete the resupply mission. It can be appreciated that in the more northern latitudes 24 hours of daylight prevails during a goodly portion of the navigation season. Therefore lights, when they are installed, would be inoperative during these periods and would only serve a useful purpose at the beginning and end of the navigation season. In several locations ranges have been erected to provide a positive line for entry into a channel or into a harbour where other devices do not adequately serve the purpose. Day beacons of varying sizes, shapes and colours have been erected on these towers to provide a visual means of alignment and setting of the course which the ranges mark.

A number of areas have been marked by different types of unlighted buoys made up in the most part from materials which are readily available on board ship or can be transported without much difficulty to the location where they are needed. We have used, for example, spar buoys made of a series of old 45 gallon oil drums welded together end to end, weighted with concrete in the bottom drum and anchored in place. These buoys may or may not last through the winter months. However, should they be lost, the cost of replacement is minimal and this loss is far less than providing for the return of one of the departmental service vessels to retrieve them. The only

difficulty which is being experienced with this type of marker is that 45 gallon drums are becoming more and more difficult to obtain in this era of bulk supply.

For the Mackenzie River system the installation of aids to navigation has gradually improved and progressed from the early days when local materials found along the route were used for support of shore markers to the more sophisticated markers in use today. Over the period of the 1950's and 60's there has been a steady increase in the number and sophistication of the aids which have been provided throughout that system. Chart No. 1 gives an indication of the types and numbers involved in this system.

Radio beacons have been installed throughout many areas of the north and consist of two types basically, aeronautical radio beacons and aeromarine radio beacons. The aeronautical radio beacons are not generally recommended for use by marine since they have been located primarily to provide the best service to aircraft and may not be suitably placed for marine use even though they may be heard by ships. Coastal refraction and intervening land masses may cause serious deflection of hearings from such beacons. The aeromarine radio beacons have, on the other hand, been so located that they can be used equally as well by marine as by air navigators.

Future Aids Requirements

The last two or three years have seen a greatly renewed interest in the north and the natural resources which are to be found both in Canadian and American territorial areas. Large expenditures have been made to assess the feasibility of constructing icebreakers to transport these natural resources from the north by sea. The most interesting exercise which has been carried out is that of the MANHATTAN which sailed through

the Northwest Passage and has this year been used to continue the feasibility studies on this whole question of large ship operation in ice infested waters. These exercises along with discussions of possible increases in marine traffic in all the northern areas have quite naturally generated some thinking and discussion on the adequacy of the present aids to navigation facilities throughout the whole area. It has meant a complete reassessment of what we are doing, a clear definition of the various terms referred to and the realization that in the future the application of the principle of recoverable financing of the Ministry's operations may be required.

"Aids to Navigation in the Canadian System are devices external to a vessel that are maintained for the marine navigator's use to assist him in confirming his position and course or to warn him of dangers or obstructions that might exist nearby." They should not be confused with the sometimes referred to "aids to navigation" equipment on the vessels themselves which are used for taking or receiving of information from these external sources. These external devices may be found either singly or as a part of a total system comprised of the different types, for use in conjunction with available hydrographic charts and other marine information publications.

In consideration of the "user charge approach" for all new facilities or additions to the existing facilities that might be provided, it must be kept in mind that this philosophy indicates that the general taxpayer will pay less of the national transportation bill than he has paid in the past and the user will pay more. It is imperative therefore that the Ministry must be more responsive to rapidly changing technology and the application of this technology to the aids to navigation system which it is providing. At the same time the system selected must be that which will provide the broadest service possible over the widest area and to the greatest

number of users. If this can be accomplished, the ultimate cost for the service provided should not change appreciably. Whether these costs are paid from the general revenue fund or by direct charges to the user they represent a very minute part of the total cost of transportation by sea. The money spent to provide and maintain an adequate system of aids to navigation will reduce the cost of sea transportation by providing for more expeditious passage of ships. The economics of an operation will therefore be enhanced.

The following comments are submitted for consideration as to the real need for aids to navigation to provide an adequate and even more than adequate service to the user of the Arctic navigation routes.

In the area of the Northwest Passage which was traversed by the JOHN A. MACDONALD and the MANHATTAN, practically no aids to navigation existed which could be of value to these ships in their passage through these waters. Discussions with mariners who had operated in these areas, mainly Masters of the M.O.T. icebreakers who have operated there summer after summer, suggested that there wasn't any real need for aids to navigation along this route. Reference to the photographs of the Arctic Islands along the way also tended to confirm these comments since the land rises very sharply from the sea, in some cases to great heights, and would obviously provide excellent radar responses. Discussions which were carried out with Ministry representatives following the MANHATTAN voyage confirmed the fact that radar along with the Arctic Pilot and some common sense was all that was needed to safely navigate through the area of the northwest passage.

There may be some locations where the land is low lying where it might be advantageous to the navigator if shore installations were made. We have been investigating the use of radar transponder beacons and, in fact, have installed them in several areas. These beacons lie dormant and do not

transmit a signal until such time as they are activated by the reception of X-Band radar signals within line of site of the unit. When so activated the unit then transmits a coded signal which appears on the ship's radar screen. The mariner is thus provided with a positive identification of a land mass, a much more positive one than can be obtained by radar reflector. Some of these units are now in operation in the Tuktoyaktuk area and on the Atlantic Coast and plans are being formulated for the installation of more of these units where positive identification of specific locations on high or low land masses is desirable.

Appraisal is also being made of the need for additional marine or marine/air radio beacons in the more critical areas as traffic develops. We are, in fact, looking into the feasibility of using standard marine radio beacons as a homing device to lead ships through channels and passages between islands and land masses which are separated by broad expanses of navigable water. This system can be used only where appropriate locations for the beacons are available such as mid-stream islands or land lying athwart the passage at a suitable distance from the channel to be marked. In some of the broad straits and sounds this device could provide guidance over long distances.

Loran, Decca, Omega, and other electronic aids to navigation of this nature, as well as satellites, are being looked at and assessed as to their usefulness or need in the more heavily travelled areas of the Arctic and more particularly at this moment in time to the Northwest Passage. Omega and satellite systems already provide general coverage and some Loran coverage is available in Davis Straits, Baffin Bay and adjacent waters. Is there a need for anything in addition to Omega, Loran and satellites as an aid to navigation for ships in the area, or are the existing systems adequate for the

degree of precision in position fixing that might be required? It has been suggested that there might be considerable advantage if a positioning device were provided, which would allow for the precise location of the ice boundary lines for easier travel either in open water or through those types of ice which present a lesser hazard or require a lesser degree of breaking. This type of information could be gathered by the use of a helicopter operating in advance of the vessel and transmitting information or readings back to the ship which could be plotted on the charts precisely. The mariner could then plot his course to take advantage of the best conditions ahead. An alternate method is to plot the position of the aircraft or helicopter relative to the ship by radar when the pilot reports "on top" of the various features he wishes to locate to the ship. This method would give the degree of precision required locally and would also provide a means of updating older and less precise reports as the ship advances.

Additional facilities that are available in the Arctic consist of radio broadcasting facilities operated by the Ministry, mostly of the aero/marine type that meet International Requirements of Distress and Calling Frequencies. These marine radio stations provide such services as ship to shore communication, weather information, ice information, traffic lists, and navigational warnings. The detail of the services provided by each of the stations and the listing of them can be seen on Figure No. 2. The geographical location of these radio stations can be found on Figure No. 3. Figure No. 4 indicates the location of the air-to-ground radio stations which are equipped with a frequency of 5803 for marine use except Inuvik which has the total international requirement.

Reference to Figure No. 5 will show the present locations of marine radio beacons in the eastern Arctic or specifically in the area of the Hudson Strait and the north end of Hudson Bay.

New Development

The Ministry is continually searching for new and improved systems, equipment and materials to withstand environmental problems existing throughout the Country. At the present time specially developed low temperature batteries provide the power source for many of our shore and buoy based lights around the Coast. These batteries have a limitation naturally, of the low temperatures at which they will function effectively and, as a consequence, some difficulty has been experienced late in the northern navigating season maintaining lighted aids. The Ministry has been investigating other power sources which are not affected by temperature to the same degree and which can provide a reliable power replacement for the present power sources.

You may have read recently of the installation of a nuclear power source "Maple 1B". This power source has a life expectancy of five years providing an output of 5 watts which is sufficient to operate the majority of our battery powered light sources. One interesting feature of this equipment is that it operates more efficiently in cold weather and, therefore, would be ideal for operation in the severe temperatures of the north. Atomic Energy of Canada Ltd., with whom the Ministry has been working on this project, will also be looking at similar power sources with larger outputs to provide a need at many of our more unattended and isolated lightstations throughout the Country. Pictures of the unit and the tower in which it has been installed can be seen on Figure No. 6. This installation has been made on the public waterfront in the Town of Brockville, Ontario, where the Ministry entered into full discussions with the local police, fire, health and municipal officials prior to its installation.

The nuclear power source complete with its protective shield was placed on the end of the pier and then a 20 ft. fibreglass tower was lowered in place over the complete assembly.

It is interesting to note also that the Ministry is making considerable use of fibreglass for tower and oil storage installations at many of its lightstations. Photographs of the installation operation can be seen on Figure No. 7.

We are anticipating considerable reduction in operating and maintenance costs. If this unit proves successful, we visualize servicing the equipment possibly every three or four years instead of on an annual basis as at the present time.

Ice has always been a problem with floating aids to navigation since not only can ice cause damage to the buoys and the equipment that might be on them, but more seriously it can cause them to be dragged off position or sunk altogether, in which case they then become a menace to navigation as opposed to an aid.

We are investigating the possibility of using buoys which can be purposely sunk below the surface of the water to a depth that would keep them below the level of the ice and yet allow them to continue producing an underwater signal which can be picked up and used by passing ships. This system has a number of applications, all of which are being looked at and, although it is in the very early stages of consideration and discussion, it indicates but another area of Ministry investigation.

A great many new devices are appearing on the market which find application in the Aids to Navigation field. These along with the existing ones, provide the Ministry with a wide range of systems and alternatives from which to choose. It is imperative therefore that the Ministry and user enter into closer discussion to establish which equipment will best serve the aids to navigation needs of the shipping industry.

TERMINAL FACILITIES

Introduction

For the discussions on Arctic terminal facilities I don't anticipate making any particular comments on those facilities in the Mackenzie River system. I think it must be assumed for the present at least that the facilities along this waterway have been developed to a reasonably sophisticated degree for the type and volume of traffic presently involved. It is agreed however that there may be several locations where improvements can be made and additional terminal facilities provided. It is a problem which is reasonably easy to deal with since there is very close contact between the user and the suppliers of the terminal facilities on an almost day-to-day basis, consequently the problem is not considered to be too acute at this time. I will therefore concentrate my remarks on the area north of the continental mainland in the western Arctic and generally north of the Hudson Straits in the eastern Arctic.

In the past it has been customary to speak of the north as a vast single region of severe climate, harsh geography, and vast distances, but it is in reality an area of considerable diversity. It comprises a significant number of different geographical regions and climatic conditions; a number of large land masses totally unconnected either to themselves or the mainland of the North American Continent. They possess varying potentials of minerals, oils and gas, some of which have already been discovered with others anticipated momentarily. They face different problems and are in different stages of economic and social development. In the overall considerations, not only in the development as a whole, but of those structures and facilities required for terminals for the shipping of these deposits, one must necessarily take adequate account of the diversities.

Programs must be adapted to the particular needs and outlooks of the various sub-regions. A number of important deposits of the natural resources have already been successfully brought into production, others have been located and are being tested and the probability is great that further exploration and investigation will continue to produce new and important findings.

Port Development

The administration of harbours in Canada has been complicated by the existence of four different federal bodies which develop and administer harbour facilities, i.e. the Ministry of Transport, the National Harbours Board, the St. Lawrence Seaway Authority and the Department of Public Works, resulting in a degree of overlapping and duplication. The Ministry of Transport is responsible for eleven Harbour Commissions, over three hundred Public Harbours and several thousand Government wharves. The National Harbours Board is responsible for ten harbours and two grain elevators along the seaway. The St. Lawrence Seaway Authority administers certain public wharves for general shipping, principally along the route of the Welland Canal. In addition there are many private wharves handling primarily, if not exclusively, the traffic of one major industry. These have been built by private capital and the Government does not become involved in the administration of the wharves although it does have control over navigation within the harbours in which they are located.

Where requests for harbour works are received by the Ministry of Transport or the Department of Public Works it is usual for these to be referred to the Interdepartmental Group on Canadian Ports. This Group consists of three representatives from the Ministry of Transport and one from

the Department of Public Works who provide the engineering input. This Group reviews the request by

(1) Collecting and studying all engineering and economic information available
(2) Carrying out an inspection of the area, and
(3) Interviewing the president and/or manager of local industrial firms to learn and assess their plans for immediate or future use of the harbour facilities should these be provided.

On the basis of the information obtained, a decision is made on what facilities, if any, are required and estimates of costs are prepared. Cost-benefit assessments are made of alternative projects and recommendations made to the two Ministers concerned.

In the establishment of some of the port or harbour facilities, differences will be seen to exist where some have been built as

(1) Public facilities, e.g. Sept Iles (Seven Islands) on the lower St. Lawrence
(2) A mixed private enterprise/public facility e.g. Baie Comeau
(3) Private facilities, e.g. Kitimat on the West Coast and Port Cartier.

There have also been instances where facilities have been built by the Department of Public Works for private enterprise which is repaid over a period of years ultimately becoming the property of the private company, e.g. Point Tupper facilities of Gulf Oil.

Reviews are presently underway to develop a new harbour administration in Canada which it is anticipated will produce a single agency of Government reporting to the Ministry of Transport, which would be responsible for all Federal activities relating to ports and harbours in Canada. The

procedures related to harbour needs will then be determined on a common basis.

In due course as the new port administration develops and all responsibility becomes centralized under this one authority, a number of procedures will change and become consolidated. It should also eliminate or at least reduce the present overlapping and duplication of the split responsibilities.

Present Facilities

In the western Arctic a number of locations are served by the Northern Transportation Company Limited along the north shores of the Continent. They service such communities as Prudhoe Bay in Alaska, Dewline installations at Shingle Point, Komakuk Beach (Shingle Point is an oil company site as well), Sachs Harbour on Banks Island, Holman Island, Bay Chimo, Gjoa Haven and Spence Bay. Spence Bay is the furthest location east that the Northern Transportation Company vessels service. These are mainly small local communities and in some cases with Ministry of Transport installations, the Hudson Bay Company, churches, etc. In every case supplies are landed by small barges or lighters onto local beaches with no wharf facilities being provided.

The two major ports that are serviced along the way are Coppermine and Cambridge Bay. Coppermine has what may be termed a small pushout type of wharf facility and attempts are being made to improve it. It is a local settlement type of supply with little or no mining company equipment being landed and no material leaving. It would appear that little or no exploration is taking place at the present time. At Cambridge Bay a steel sheet pile wharf with a 30 ft. face and approximately 40 ft. in depth, joined to the shore by a gravel and rock breakwater, has been provided. Again this is mainly a settlement supply operation. The Dewline station which is located nearby is serviced separately by a beaching area.

In both the eastern and western Arctic, efforts have been made to provide facilities for vessels to tie-up to and in one case to eliminate the need for anchoring off and landing or receiving cargo by lightering facilities. In the case of Frobisher Bay, which has a 35 ft. to 40 ft. tide, a 750 ft. jetty was built several years ago from material blasted out of the local rock formation. This jetty has unfortunately disintegrated to the point where it is no longer useful and requires some major maintenance to put it back in operation. Ships are thus required to revert to the old system of discharging their cargo into lighters whilst at anchor. These lighters are beached just after high tide and are discharged before the tide reaches them again.

At Tuktoyaktuk in the western Arctic, wharf facilities were constructed on wooden piles and during the course of the first winter the ice, which had formed totally around the piles, gradually worked the piles out of position with the rise and fall of tides, and the wharf by spring was unusable. This problem has been overcome by repositioning the piles and installing a bubbler system which reduces the amount of ice formation and keeps whatever ice might form in motion. The Northern Transportation Company found it necessary to build a new steel sheet piling wharf at the main Tuktoyaktuk site and have been able to maintain service at this location without any difficulty.

Generally speaking, in the north, tides present little or no problem, varying from a few inches to little more than a couple of feet. On the other hand, wind can present real problems if it has a long fetch and can cause the water to pile up and produce, in effect, a tide of several feet under severe conditions.

Required Research and Study

It can be seen from the foregoing that should any attempt be made to provide normal wharf or berthage facilities in the north, a careful study of all the natural forces must be made to ensure that these structures will be built to maintain their continued and uninterrupted use. It would also appear that assumptions have been made with very limited pre-engineering or on-site investigation of the actual ice, storm, tide and general conditions which prevail in the areas. The extent of knowledge of ice forces is limited. Although research is being carried out in many areas of this Country on this subject, it might be said that a more concerted effort needs to be made by Canada to provide complete details of ice and its strength for all design purposes.

It has been said that Coppermine is the dividing line on the mainland between the oil and gas explorations to the west and mineral explorations to the east. Through the northern islands this line moves eastward to the vicinity of northwestern Baffin Island and Devon Island. The area from Coppermine westward has come into great prominence in the last few years with the Prudhoe Bay oil discovery on the northern slopes of Alaska.

It has received even greater interest by the voyage of the MANHATTAN through the Northwest Passage to Prudhoe Bay and this has generated in turn engineering and economic studies on the possible development of terminals in the Tuktoyaktuk, northern Yukon and Alaska areas for a harbour from which the materials can be shipped. Through this area west of Coppermine great distances of northern shoreline become inaccessible for normal shipping due to the relatively shallow waters extending well out into the northern seas. These shallow waters extend out distances of 20 to 30 miles before depths

of 30 ft. or more are encountered. In general terms it might be said that the shallow water extends out approximately 3 to 4 miles to the 5 fathom line and approximately 8 to 10 miles at the 10 fathom line. This remains fairly regular along the coast until you reach the Tuktoyaktuk area where depths of this nature will be found at a distance of 25 to 30 miles beyond the shore which gradually decrease back to the 3 to 4 mile range towards the Alaska border.

In the western Arctic areas under discussion, problems of navigation exist affecting the movement of the ships directly in the form of very strong winds and currents. The effect of the ice, both solid and broken, adds additional grave problems of navigation and should dredged channels have to be navigated under these conditions ship movements would become very difficult indeed. The question of whether vessels could in fact operate is still a big question. Consequently it might be proposed that ships should be able to approach terminal facilities in a position nearly parallel to the coast under power and then move forward under power as they leave the terminal in a sort of drive-in-drive-out system. This would help to alleviate difficult maneuvers and reduce tug assistance to a minimum.

The construction of terminal facilities in the north requires very careful consideration of all the requirements. It is unfortunate that the mining, oil and gas exploration development companies cannot tell us in advance where their major terminal facilities are likely to be required.

The geographic and weather problems which prevail in the western Arctic and the cost that might be associated not only with the construction of terminals but the shipment from these terminals through the Northwest Passage suggest that the oil industry might be looking more closely at possible oil

sources in the Resolute, Viscount Melville Sound area. If any success is realized in these areas, the construction of terminal facilities with deep water and reasonable protection might be more readily located. Certainly they are closer to the more open and more easily navigated waters of Baffin Bay and Davis Strait. Studies have been carried out by private industry and with some input from Government on the possible location of terminal facilities at the north tip of Baffin Island in the area of Wakeham Bay, Diana Bay and Deception Bay. Considerable expenditures of time and effort have been involved but none have been developed.

Many problems are present in the north in the provision of terminal facilities either by private interests or by Government, along with their associated and necessary services like aids to navigation. We can all learn from the experience of others as expertise in northern terminal requirements is quite limited. It therefore becomes of interest to both groups to enter into much closer discussions to ensure the best locations and designs of marine terminals are achieved.



TYPE OF APPARATUS	TUKTOYAKTUK TO ARCTIC RED RIVER	ARCTIC RED RIVER TO FORT GOOD HOPE	FORT GOOD HOPE TO FORT NORMAN	FORT NORMAN TO WRIGLEY	WRIGLEY TO FORT SIMPSON	FORT SIMPSON TO GREAT SLAVE LAKE	GREAT SLAVE LAKE	GREAT BEAR LAKE	TOTAL
SHORE LIGHTS	21	14	20	20	18	30	42	23	188
BUOY LIGHTS	3	—	—	—	—	8	10	—	21
BEACONS	87	111	83	84	86	111	201	—	763
BUOYS	227	34	85	11	11	35	40	5	448
TOTAL	338	159	188	115	115	184	293	28	1420

FIG. Nº 1

	Ship to Shore	Weather	Ice Information	Traffic Lists	Navigational Warnings
Resolution Bay	x	x	x	x	
Resolute	x				
Frobisher	x	x	x	x	x
Coral	x	x		x	
Cape Hopes Advance	x	x		x	
Cambridge	x	x	x		
Coppermine	x	x	x		
Inuvik	x	x	x		

FIGURE NO. 2

COAST STATIONS FOR INTERNATIONAL SERVICES

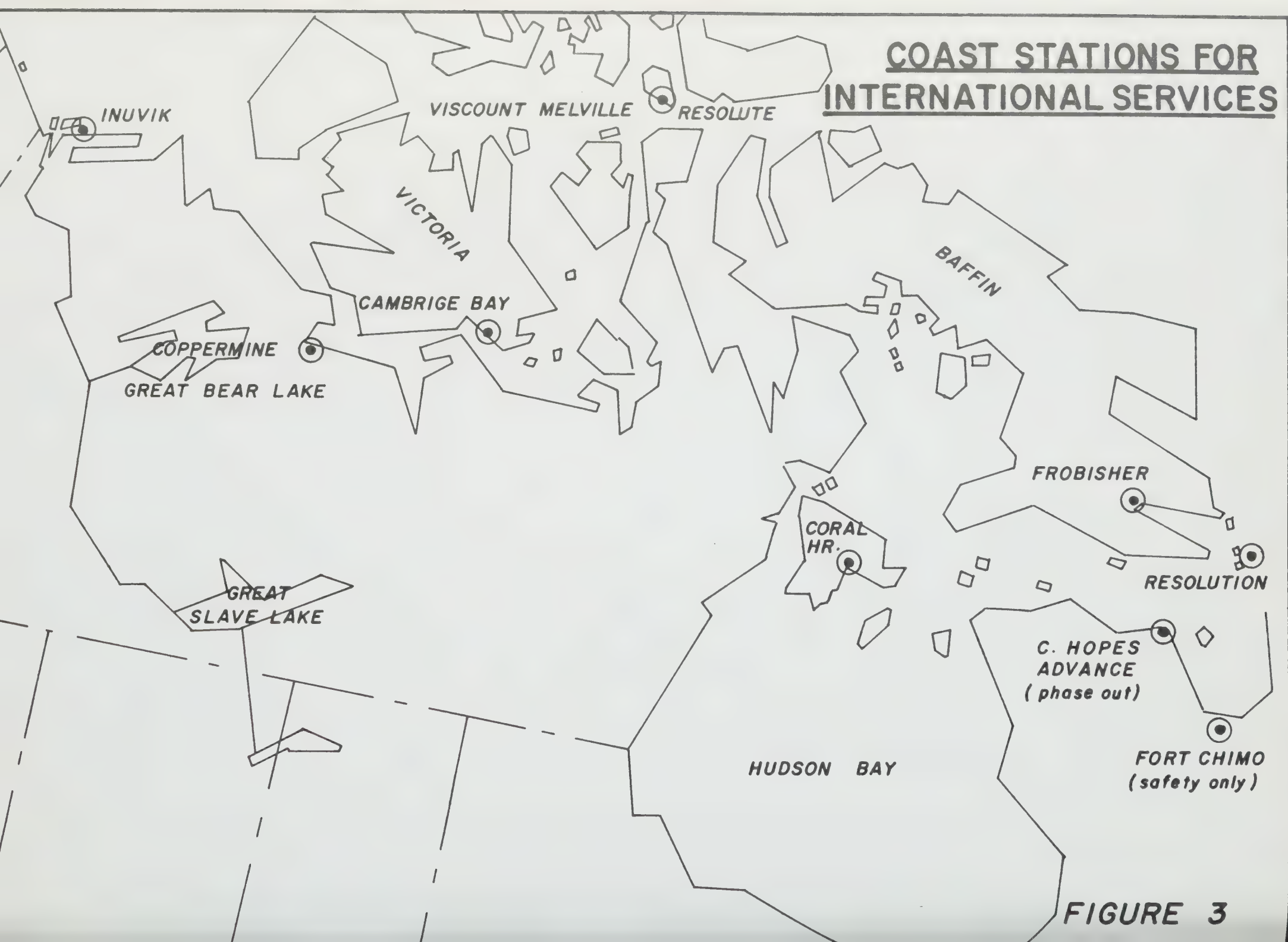


FIGURE 3

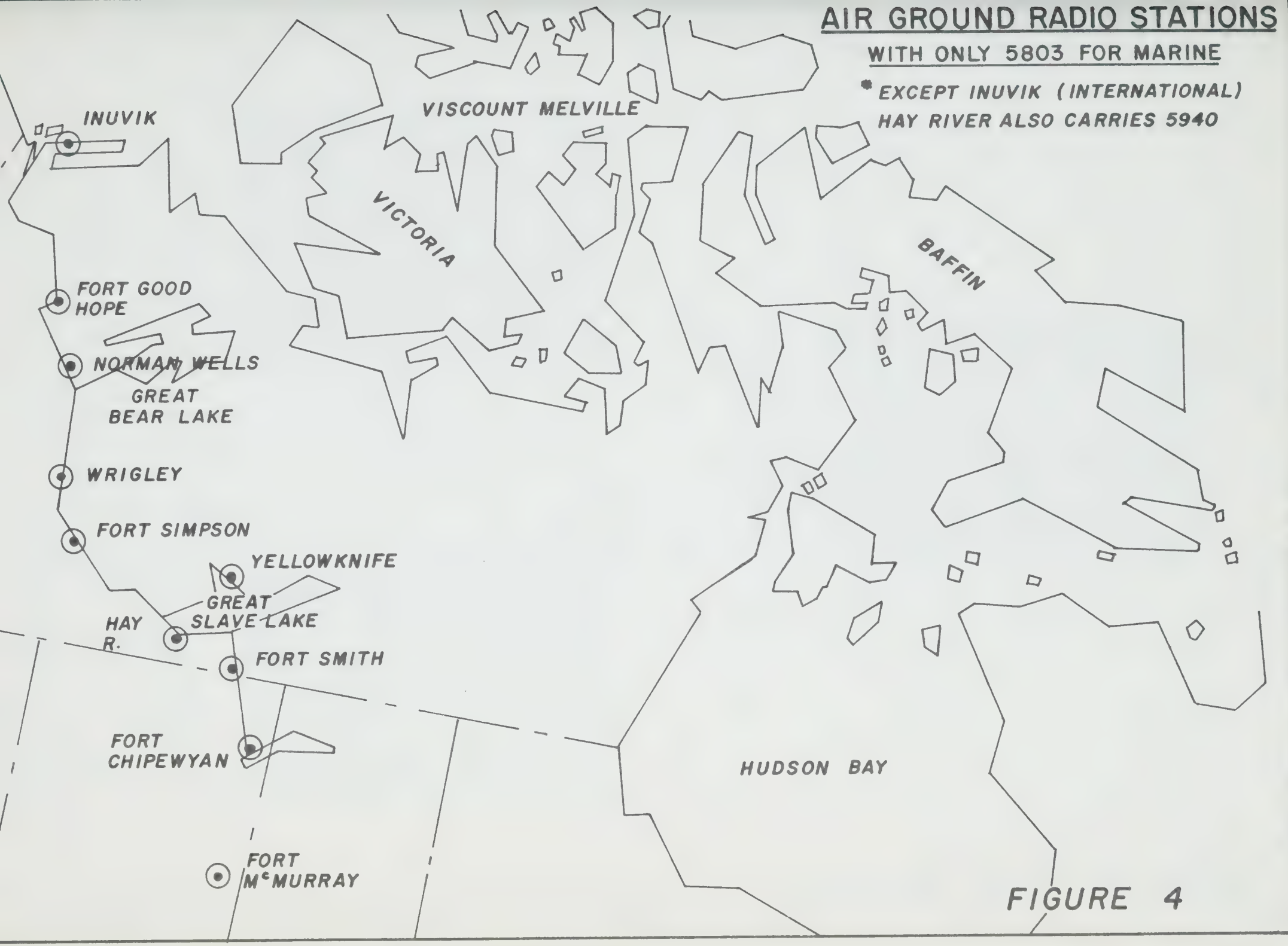

AIR GROUND RADIO STATIONS
WITH ONLY 5803 FOR MARINE
* EXCEPT INUVIK (INTERNATIONAL)
HAY RIVER ALSO CARRIES 5940
INUVIK
VISCOUNT MELVILLE
VICTORIA
BAFFIN
FORT GOOD HOPE
NORMAN WELLS
GREAT BEAR LAKE
WRIGLEY
FORT SIMPSON
YELLOWKNIFE
GREAT SLAVE LAKE
HAY R.
FORT SMITH
FORT CHIPEWYAN
FORT McMURRAY
HUDSON BAY

FIGURE 4

MARINE RADIO BEACONS

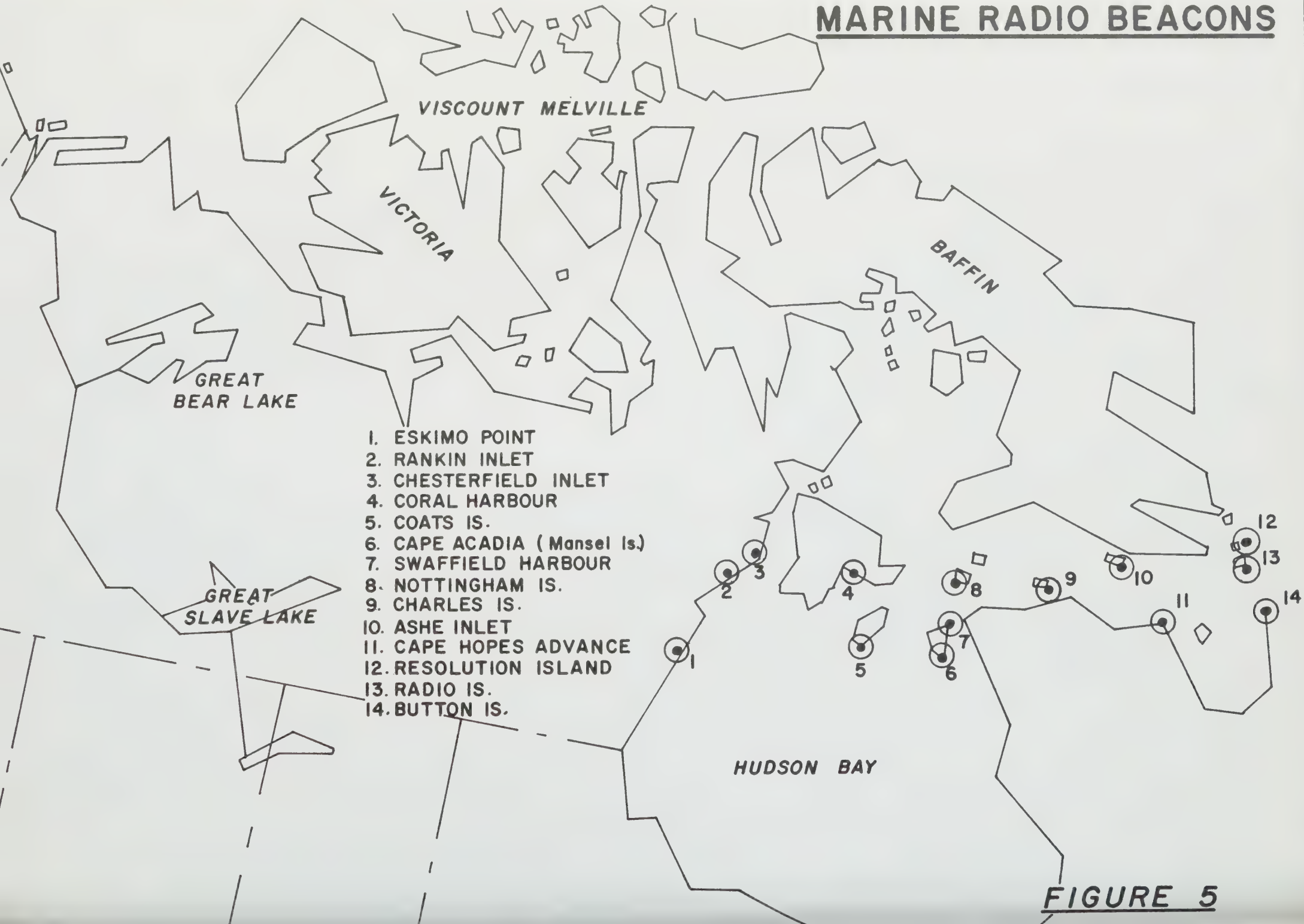


FIGURE 5



LOWERING SHIELD OVER
NUCLEAR POWER SOURCE



PLACING FIBREGLASS
TOWER



INSTALLATION
COMPLETED

FIGURE 6

ICE INFORMATION SERVICES IN THE ARCTIC

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SUMMARY

What is involved in providing, during the 1970's, the best possible information service on the floating ice cover of Canadian and contiguous waters?

This is the question that is examined in this background paper.

Northern residents are affected more directly and more frequently than are most residents of southern Canada by the ice cover of Canadian waters. Information about the ice is of direct value to many people, for example, the ship's captain, those using ice in surface travel and as landing strips, the marine architect, the biologist, and the weather forecaster. Whenever this information results in more efficient operations or leads to a better understanding of environmental conditions in the north, it benefits all northern residents and, indirectly, all Canadians.

Ice information capable of meeting the needs of the 1970's requires an expansion of work in two areas; research, and the provision of information to those engaged in ice sensitive activities. Many public and private agencies are working in these areas. Close co-ordination is needed to ensure maximum benefits from the expanding effort that will be going into ice work in the years ahead. Scientifically, this co-ordination is achieved through the Working Group on Ice in Navigable Waters of the Canadian Committee on Oceanography. Operationally, there is a need for closer co-ordination among the several agencies that now provide and use information on ice in the major river-lake systems in Canada.

One of the major objectives of the Canadian Meteorological Service (CMS) falls into the second area noted above - the provision of an ice information service to those engaged in ice-sensitive activities. An examination of the needs for ice information and of the special knowledge of various scientific disciplines suggests that the CMS should concentrate on the provision of information on the distribution and characteristics of ice floating in large water bodies. The provision of ice information services in rivers and the carrying out of basic research on the ice environment are fields in which other federal agencies, agencies of other governments, and the universities play the major part.

This paper deals primarily with the CMS ice information service, with emphasis on its use to transportation in the Arctic. Other applications

are mentioned, as are requirements for ice research and the ice services provided by other agencies, but these topics are not dealt with in the depth which their direct or indirect contributions to "Arctic Transportation in the Seventies" may well deserve.

Comparison of the services that the CMS is now providing with the services needed to satisfy present and anticipated demands reveals the following major deficiencies:

(a) Operations in difficult ice require more detailed and more frequent observations than are being provided;

(b) Little quantitative information is available on the climatology of floating ice or on the processes affecting its formation, motion, and dissipation;

(c) There is no central clearinghouse in Canada to which consumers can turn for information on the ice environment;

(d) Longer-range ice forecasts are needed;

(e) The data-acquisition facilities used in the ice program and the ice data that are now available are not being fully exploited, especially in fields not directly connected with marine transportation.

Scientific and technological capabilities are now sufficient to allow many of these deficiencies to be overcome. (An exception is the provision of long-range ice forecasts, which must await some fundamental ice research and development of longer-range weather forecasts.) The major changes in the CMS Ice Information Services System would be:

(a) Establishment of an Ice Climatology Unit;

(b) Establishment of an ice data advisory and clearinghouse capability in Ottawa;

(c) Conversion of the data acquisition program from visual observations to remote sensors on aircraft.

The first two changes are necessary to achieve optimum use of the data that are now being acquired. They are natural extensions of the present ice information service.

The last-named change, conversion to remote sensors, is one of wider impact. It is an essential change if frequent and detailed information is to be provided to operations being conducted in difficult or dangerous ice conditions and if the severe restrictions imposed on visual observations by Arctic weather and daylight regimes are to be overcome. It would provide more and

better data for operational and statistical processing with resulting improvements in the services provided to those engaged in ice-sensitive activities. It would lead to quantified measures of the type needed in modern problem-solving techniques and in scientific work. Finally, an ice services system using remote sensors in suitable airplanes would provide important side benefits in such areas as the establishment of standards and regulations, pollution detection, Canadian sovereignty in the Arctic, and ecological and environmental studies.

To answer the question with which this summary began, the best possible ice information service on the floating ice cover of Canadian and contiguous waters will be obtained by:

(a) Expanded ice research activities;

(b) Close coordination of effort by all agencies, public and private, engaged in ice research or in the provision of operational information services;

(c) An Ice Services System concentrating on floating ice in large water bodies, consisting of Data Acquisition, Climatology, and Forecast and Data Advisory Units, and using as the primary source of raw data, remote sensors in suitable airplanes.

1. INTRODUCTION

The severe Arctic environment controls the activities of man in the north. At the same time it is becoming increasingly evident that Arctic ecosystems themselves are peculiarly sensitive to man's activities, and that changing conditions in the north may have influences not only locally, but far beyond the boundaries of the Arctic.

With such delicate interactions between man and his environment, detailed knowledge of that environment is essential.

The ice cover of northern waters is a vital factor in the Arctic environment. The effects of this ice cover can be identified, exploited, or avoided only if adequate information on its extent and nature is available. One of the objectives of the Canadian Meteorological Service (CMS) is to provide this information.

The purpose of this paper is to examine the needs for ice information in the Arctic, to outline the ways in which modern technology can be adapted to meeting those needs, and to suggest the courses of action that should be followed in providing information on the ice environment in the years ahead.

2. PERSPECTIVE ON THE CMS ICE INFORMATION SERVICE

The Canadian Meteorological Service (CMS) has been responsible since 1958 for the provision of information on the ice cover of navigable waters within and contiguous to Canada. Expansion of ice sensitive activities, especially in marine transportation, began to strain the CMS ice system to its limit in the late 1960's. Faced with the likelihood of further expansion of ice sensitive activities during the 1970's, especially in the Arctic, the CMS set up an Ice Information Services Planning Project in November, 1969, to determine what ice information services will be required in Canada during the 1970's to meet the needs of the national economy and to meet international obligations in the exchange and dissemination of environmental data.

This paper is an adaptation of the report produced by the Ice Information Services Planning Project. There are important differences between the ice cover in the Arctic and the winter-time ice cover in more southerly waters, and the weather and sunlight regimes of the Arctic create special problems in observing the ice. However, the techniques of data acquisition, collection, processing, archiving, and distribution are essentially the same, and a single ice-services system is the most effective and efficient way of meeting operational requirements in all of Canada. For this reason, no attempt is made to define the Arctic precisely for purposes of this paper and it should be kept in mind that the Arctic is but one of the regions of Canada where ice information services are required.

The CMS ice information service has been, and is, closely linked to the needs of ships. Given this historical orientation, the fact that the CMS has always been a component of the Ministry of Transport, and the transportation theme of the conference, it will not be surprising if the use of ice information in transportation receives more emphasis in this paper than do other applications. The objectives of the CMS include service to all sectors of the national economy, and in the years ahead applications of the ice service in fields other than transportation will receive increased study.

The CMS became involved in the provision of ice information because of two major factors. Firstly, the meteorological community has developed skills in the acquisition and handling of vast numbers of data in order to describe and predict environmental conditions over very large areas of the globe, and in disseminating this information in real time (i.e. in time to be used in operational decision making). These skills are applicable to the provision of service on the ice environment. Secondly, the meteorological elements of wind and temperature are dominant controls in the formation, movement, and dissipation of floating ice.

These two factors result in certain constraints on the ice services provided by the CMS. The operational system concentrates on a broad overview of the ice environment at given points in time, rather than the continuous monitoring of ice conditions at a given point or detailed study of a particular ice feature during its life history. Forecast services concentrate

on conditions where meteorological rather than hydraulic controls are dominant. Finally, CMS involvement in research is oriented directly to its particular mission - the observation and prediction of ice conditions in large water bodies. The CMS is extremely interested in the results of basic research on ice, and is often in a position to assist such research with its data-acquisition system. However, most ice research is conducted by other agencies, both public and private.

3. FACTORS AFFECTING ICE SERVICES IN THE 1970's

3.1. Requirements for Ice Information

Ice information is needed in four classes of activities: marine operations (conducted in water); surface operations (conducted on ice); the control of water levels, rates of flow, and the ice cover; and scientific services.

The most important class from the point of view of operational ice services is marine operations. Shipping is the most important subdivision of the class. Ice data in the shipping industry is used in long and short range planning (requiring information on ice climate and on general ice conditions during a particular season) and in navigating a ship in ice congested waters (requiring more detailed information on the location and characteristics of the ice packs and, in difficult ice conditions, very detailed information on the ice flows, ice ridges, leads, etc.).

In the Arctic, the high costs of marine transportation are due largely to the thickness and strength of multi-year Polar ice and the short (or non-existent) ice-free season. Experience in the Gulf of St. Lawrence has shown that the combination of modern ships, ice advisory services involving icebreaker deployment and suggested shipping tracks, careful navigation when in ice, and an effective ice information service, can produce marked extensions in the shipping season. Economic savings result from more efficient operations, and also from lowered insurance rates. Similar changes are likely in the Arctic, with direct benefits to northern residents from lower shipping costs.

Fixed-point operations and structures, such as cargo handling, offshore drilling, navigation aids, underwater pipelines, and harbour installations, constitute an increasingly important subdivision of marine operations in northern Canada. Information on ice climate enters into the selection of sites, and data on the pressures that ice can exert affects the design of structures. During operations, up-to-date information on the location and motion of floating ice may be essential - the striking example of icebergs threatening a drill site may soon become a reality off the Labrador coast.

Surface operations use the ice as a bearing surface. These

operations are particularly frequent in the north where bulk supplies are transported on winter roads, where many ice landing strips are used, where ice islands support semi-permanent scientific and weather stations and have been studied as possible ice docks, where a good deal of travel in the Archipelago is conducted on sea ice, and where ice floes and fresh-water ice may be used in military and search-and-rescue operations. These operations can benefit from information on the ice, especially on the bearing strength, on scales ranging from the climatological to small-scale spatial and time variations at particular locations.

Water flows and levels are controlled in some inland waters for such purposes as hydro-electric power generation, flood prevention, protection and use of shore properties, and maintenance of depth for shipping. Ice conditions, actual or expected, can affect the control measures that are taken, and water control measures can themselves affect ice conditions. Ice booms may be used to increase man's control over the ice cover, hastening the establishment of a fast-ice cover in the fall (thereby cutting down the rate of ice production in flowing open water and reducing the risk of ice jams) and holding the ice in place in the spring until it rots sufficiently to pose no problems when it starts moving. Successful handling of these controls requires knowledge of the complex ice-water-air heat exchange processes in flowing water, and detailed observations during critical periods.

Scientific services of several kinds require information on the ice environment. Weather conditions both locally and over large areas are influenced by the distribution of ice. Information on ice distribution and on the heat exchange processes between ice, water, and air, is required by meteorologists, oceanographers, and hydraulic engineers in the energy budget studies that are so important to an understanding of the earth-ocean-atmosphere system (and to better forecasts of events such as the early freeze-up in the western Arctic this fall). Flood forecasters need data not only on ice in rivers, but also on the floating ice in lakes and seas which may jam up in river mouths and contribute to flooding well upstream. The biologist is interested in relationships between the ice cover and life forms, and the ice cover is an important control, direct or indirect, in many Arctic ecosystems.

Sampling techniques preferred by scientific workers differ from those that best suit other ice-sensitive activities. In the long run a scientifically-designed technique provides knowledge of use to society as a whole. However, the needs of an icebreaker in heavy ice in Baffin Bay or of an offshore drill rig in Hudson Bay are more immediate and more likely to be met than the needs of the research worker, ice climatologist, or ice forecasters for a regular observational program over the ice cover as a whole.

It is difficult to establish criteria for a scientifically-sound ice-observing program. Such criteria await precise specification of the parameters required and the accuracy of measurement needed, and more information on the natural variability of the phenomena. Weekly sampling appears to be adequate to outline the distribution of major ice fields when the latter are floating freely. Less frequent sampling would probably be adequate

to sample changes in the compact or consolidated pack that covers the Arctic Ocean, and, for much of the year, most channels in the Canadian Archipelago. On the other hand, studies of the motion and modification of ice may require almost continuous observations in a restricted area or of a particular ice feature.

Present observational methods cannot provide, over large areas and in large numbers, quantitative measures of many of the critical properties of ice fields - properties such as thickness, strength, internal pressures, roughness of top and bottom surfaces, and albedo. Solution of these observational problems is essential for a better understanding of the ice cover, which leads in turn to better ice analyses and forecasts for use in marine and surface operations, water control work, and scientific services.

An examination of the present and future needs for ice information in these four classes of activities and of existing ice information services in Canada leads to the following conclusions of importance to the planning of an effective ice service for the 1970's.

(a) Ice services are now designed primarily to meet the needs of the shipping industry - only one, albeit the most important, of the user groups in Canada.

(b) Modern methods of problem-solving will increase the demand for quantitative ice information in a form suitable for use in objective techniques.

(c) Whether or not year-round navigation in the Arctic is achieved, new procedures and the increasing capability in ice of modern ships will result in further seasonal and geographical expansion in ice navigation and hence in similar expansion in ice reconnaissance and forecast coverage.

(d) Ice information is required on many different space and time scales.

(e) Variations in ice properties are greater in the Arctic pack than in the first-year ice found in more southerly waters, putting additional pressures on the ice services system when information is being provided for Arctic regions.

(f) There are important scientific requirements for ice observations that tend to take second place to immediate operational needs; a scientifically-oriented sampling program would have both direct and indirect benefits for the national economy and is essential for an accurate appraisal of the Arctic ice cover and its role in man's global environment.

(g) There are special problems in restricted waterways where currents are strong and hydraulic controls are important.

3.2. Ice Measurement

An Analysis of ice sensitivities combined with the nature of the ice cover leads to the identification of five types of ice information:

(a) Micro-scale measurements - chemical, crystalline, mechanical, electrical and thermal properties;

(b) Meso-scale measurements - the dimensions and physical properties of the component parts (floes, leads, ridges, etc.) of ice fields in large bodies of water and the dynamic and physical relationships between these component parts (pressure effects);

(c) Synoptic-scale measurements - the concentrations, frequencies of occurrence, and average values of physical properties, that distinguish one ice field from another;

(d) Measurements in rivers and narrow channels - rate of ice formation, speed of ice motion, growth rate of ice jams, the hydraulic effects of ice, and rates of energy and heat exchange in the water-ice-air system;

(e) Statistics which can be generated from series of measurements of ice properties (averages, extremes, return periods, etc.).

Of these, micro-scale measurements require laboratory analysis of ice samples or specialized field experiments and are beyond the scope of an operational ice program, except where correlation techniques permit inferences of physical properties to be drawn from other, indirect observations of ice. Ice conditions in rivers require special observational techniques. This leaves three types of ice information of particular concern in the operational program: mesoscale, synoptic-scale, and ice statistics.

The provision of an effective ice service to all classes of users depends on the present and future availability of these three types of information. At present only synoptic-scale data are acquired and the observations are subjective visual estimates, more qualitative than quantitative. Improvements depend on the development of objective methods of measuring meso-scale properties quantitatively. In the seventies, improvements will be based on the use of remote sensors operating in many ranges of the electromagnetic spectrum. The sensors in satellites will provide increasingly valuable data during the decade, but airplanes will continue to be the essential observational platforms for the acquisition of the basic data on ice.

3.3. Real-Time Information Services

Real-time services can be sub-divided into meso-scale and synoptic-scale services in salt waters, services in inland waters, and statistical services. An examination of these services brings out several points of

interest.

(a) At present, CMS real-time services are limited to synoptic-scale information on pack ice in salt waters (little information is given on ice of land origin such as icebergs).

(b) Meso-scale real-time services are a practical area of involvement for the operational ice program because of the relatively slow interaction between the ice environment and the marine interests that are the prime users of real-time services.

(c) For meso-scale services, there is no satisfactory alternative to a selection of non-visual remote sensing devices and an integrated continuous positioning system on suitable aircraft. A combination of a navigation system giving DECCA-type accuracy and SLAR (side looking airborne radar) offers promise for real-time service to operations in difficult ice as well as for general survey applications. Daily service is desirable in many operations.

(d) The usefulness of synoptic-scale real-time services would be increased by:

(i) The extension of forecasts into the three to ten day range as soon as wind forecasts and knowledge of water currents permit;

(ii) A computer-based system for quality control and analysis of ice data from all sources;

(iii) The higher-quality and more numerous data that would be acquired from remote sensors on planes;

(iv) Better knowledge of the processes of formation, motion, deformation, and melting of sea ice;

(v) The development of objective forecast techniques.

(e) Real-time services in inland waters are now provided only on the St. Lawrence River downstream from Montreal.

(f) Real-time statistical services await the generation of ice statistics and the establishment of communications links between the statistical centre and the users.

A question that requires examination at this point is whether a remote sensor data-acquisition system based on SLAR and a DECCA-type navigation system can provide an effective ice service. There is not much concrete information available on SLAR because until recently it has been classified for security reasons. However, the equipment has been tested along the St. Lawrence by Ministry of Transport ice reconnaissance experts and by the U.S.

Coast Guard during the Manhattan experiment. A verbal report given by a member of a USCG party visiting the Atlantic Oceanographic Institute, Bedford, in December 1969, was quite optimistic. So is the assessment of the CMS specialists. From the point of view of navigation in Arctic ice, the Director of the Marine Operations Branch outlined his views on the desirability of such a system to the Seventh Marine-Meteorology Committee Meeting held in Toronto in January, 1970. Thus, the system is expected to meet the test of effectiveness for both the scientist and the seafarer.

Research is being conducted on the use of many remote sensors other than SLAR. Developments in passive microwave and laser profilometry, multispectral and multi-sensor tests on ice being conducted in the United States, Russian and Japanese work with standard radar, and tests of infrared radiometers in Canada, all have potential applications. The best data-acquisition system will use several sensing devices.

3.4. Communications

Fast, reliable communications are essential in the provision of real-time services. Data from ships, shore stations, reconnaissance aircraft, and satellites must be collected for processing, and within a few hours the analyses and forecasts must be on the way back to the user. Also, aircraft reconnaissance reports must be relayed directly to those users who need close tactical support.

The ice services system uses meteorological and commercial communications networks to relay information by voice, written messages, and pictures. Pictorial methods are effective and efficient, and facsimile is being used more and more within the system and between the system and the consumer. The Arctic is served by radio facsimile from Edmonton and Halifax. Reception is quite variable. This could be solved by establishing a microwave link for facsimile between Hay River and the Dew Line, with subsequent low frequency facsimile broadcasts from Cambridge Bay. Funds are not yet available for the establishment of this facsimile system. When it is set up, it will serve to get ice reports out of the Arctic to Ice Central as well as improving service to facsimile-equipped users in the north.

New communications problems will be created by the vast numbers of data that will be acquired by remote sensors. Looking ahead, satellite communications systems will likely be important in future ice information services.

3.5. Advisory Services

Requests for advice on the availability and methods of use of ice data have become more frequent and more varied in recent years. To answer these requests, knowledge must go well beyond the knowledge of meso-scale, synoptic-scale, and statistical data that would be the usual concern of the operational ice program of the CMS.

The Working Group on Ice in Navigable Waters of the Canadian Committee on Oceanography (CCO) has directed particular attention during the past two years to the urgent need for an ice information centre in Canada which would act as a central repository for ice data, provide assistance in interpretation and use of the data, and, if necessary, direct the user to other sources of information.

The requirements for ice data advisory services can be met by establishing:

(a) An ice data advisory centre co-located with the Marine Operations Office in Ottawa;

(b) A computer-based archiving, statistical processing, and consultation centre in the form of an Ice Climatology Unit in the Climatology Division of the CMS, Toronto.

The ice data advisory centre would have to maintain close ties with other centres handling related oceanographic and water-resource data, with operational units and the Ice Climatology unit of the CMS, with agencies providing ice information services in river systems, and with the ice research and development community.

3.6. Ice Research

The CCO Working Group on Ice in Navigable Waters plays the central role in co-ordinating sea ice research in Canada. The Working Group has prepared a report on Sea Ice Research dated November 1969 which contains a great deal of information on present and needed research programs. Under the heading, Future Plans, the report states: "Activity at the moment is still needed the most in the mission-oriented fields.....".

The Montebello Seminar on Arctic Research Needs also made explicit recommendations on the importance of sea ice research. In part they are:

> "The highest priority is given to essentially everything connected with sea ice. Intensive studies are essential in the open ocean and peripheral seas and even more so in restricted passages".

Included in the list of the ten most critical studies were energy exchanges with both atmosphere and water interfaces, ice distribution and change with time, nature and causes of pressure in ice, seasonal variations in distribution of ice versus open water and the nature and extent of grounded sea ice. In 1968 an Ice Seminar co-sponsored by the CCO Working Group on Ice in Navigable Waters and the Petroleum Society, Canadian Institute of Mining and Metallurgy, concluded that a great deal more detailed information on ice conditions in Canadian waters ranging from the Grand Banks off Newfoundland to the Arctic Ocean will be required before the challenge of developing Canada's offshore oil potential can be fully met.

The Ice Information Services System of the CMS is involved with research as a beneficiary of, and participant in, projects which may have results applicable to the forecasting and observing of ice, and also as a provider of data to the research community. The implications on the later role contained in the references noted above, can be summed up in a quote from Untersteiner (Arctic, Vol. 23, No. 3, Sept. 1969): "The present limitations are in data and data processing rather than in concepts and ideas".

3.7. International Commitments

Canada is a member of the World Meteorological Organization (WMO) which, through the Commission for Maritime Meteorology, plays an important part in establishing international arrangements for the provision of weather and ice services to shipping. Canada's area of responsibility for shipping forecasts is defined in the publication WMO No. 9 TP 4, Vol. D, Information for Shipping (Part A):

> "13.1.2.4. Canada: North Atlantic waters west of 35°W, Labrador Sea, Hudson Bay and other Arctic waters off Canadian territory, between the western coast of Greenland and 170°W".

Under the World Weather Watch (WWW) plan of WMO, provision is made for the establishment of Regional Meteorological Centres (RMC) to provide processed data in specialized fields such as ice services. An ice RMC would contribute to a strong Canadian voice in international affairs involving marine operations in ice-congested waters.

3.8. Additional Benefits from Ice Reconnaissance

The CMS ice services system using aerial reconnaissance in support of shipping has provided some side benefits in the past. These might be considerably expanded, particularly in the Arctic, by a system using modern technologies. Such benefits might be found in the following areas:

(a) Political advantages from regular, year-round surveys of Canadian and contiguous waters, in the Arctic and elsewhere, for peaceful purposes;

(b) Advantages accruing to Canadians generally, and Arctic residents particularly, if a modern ice information service were provided by a Canadian government agency rather than by private concerns in support of particular operations (such as the export of Arctic resources in bulk carriers);

(c) Search and rescue work;

(d) Aircraft weather reports from areas of sparse data, contributing to better weather services in the north;

(e) The establishment of baselines for ecological and environmental studies;

(f) The detection of the effects of development projects, including pollution detection;

(g) Wildlife surveys.

3.9. Participation of Northern Residents in the Ice Program

A store of first-hand, practical knowledge of the ice environment is held by the residents of Arctic Canada, particularly by the Eskimos. To date, the Ice Information Services System of the CMS has not been very successful in tapping this source of information in its day-to-day operations.

An obvious way of augmenting the flow of data is to expand the network of surface stations reporting on ice conditions. This might be done cheaply in the case of climatological reports collected periodically. For real-time use, however, the problem of communications must be solved, and this would be difficult and expensive in the case of the outlying settlements from which the data would be of greatest value. Of course, the acquisition of usable data would also require that the observers have adequate knowledge of the procedures, codes, and terminology that are in international use.

Participation of northern residents in the other activities of the Ice Information Services System is also most desirable. A welcome awaits any who can meet the qualifications for Ice Observers, Ice Forecasters, and other specialists in the System.

4. ALTERNATIVES

Depending upon needs and availability of resources, the Ice Information Services System of the CMS can take one of two courses during the 1970's. These two courses can be called the Arctic-summer Program, and the Year-round Program.

4.1. The Arctic-summer Program

The service would continue, as it is now, to be based on visual observations and satellite pictures taken in daylight and in good weather. The service provided would be predominantly in the synoptic scale, and the requirements of shipping would be given priority over the needs of other user groups.

4.2. The Year-round Program

Under this course of action, the goal would be an ice services system providing a full range of meso-scale, synoptic-scale, and ice climatology information to all classes of users. Such a system would be based on

the use of remote sensors carried on modern high-performance aircraft. It would have several features of particular value in the Arctic:

(i) Ice information could be provided during the dark period;

(ii) The wide variations in the characteristics of polar ice could be observed objectively;

(iii) A body of data on the ice environment would be built up more rapidly than is now possible and it would be objectively measured data that could be quantified;

(iv) The system would be able to respond more effectively to expanding requirements for services in the north.

4. TIMING CONSIDERATIONS

The greatest pressure on the CMS Ice Information Services would come from the use of giant bulk carriers in ice-congested waters, particularly strengthened vessels operating in the Arctic. At one extreme, such ships could start operations late in 1973 and achieve a 10-12 month season in all or part of the Northwest Passage by 1975. At the other, economic and political factors may prevent any export of Arctic resources by surface or subsurface shipping during the next decade or longer.

For the Ice Information Services System, the critical timing factor in meeting the maximum requirements possible in the Arctic would be development of the data-acquisition system. Obtaining new aircraft, equipping them with remote sensors, and operational testing would take at least two years.

Whether or not bulk carriers come into use to export resources from the Arctic, the CMS is faced with the problem of meeting increased "normal" requirements. Data-acquisition capabilities are again the key.

Development of data processing and archiving facilities would have to keep pace with any expansion in data-acquisition capability to ensure maximum value from the increased flow of data. Expansion of archiving, statistical, and consultation facilities is urgently required to utilize presently-available data to best advantage.

6. FINANCIAL CONSIDERATIONS

The cost estimates below cover only the ice information services of the CMS and are based on 1971/72 rates.

6.1. Arctic-summer Program

Annual costs of the CMS ice information program are now about $1.6 millions. Data acquisition accounts for over 90% of this total - nearly $1.5 millions. It is estimated that these costs will increase by 1975 to over $4 millions annually owing primarily to increased costs for leasing of suitable aircraft and to increased flying time needed to provide tactical support to icebreaker activities.

6.2. Year-round Program

In estimating the costs of the year-round program, it has been assumed that purchase of suitable aircraft would be more economical than leasing in view of the requirement for exclusive use. The estimated capital costs are $20 million: the operating costs are estimated to be about the same as cost of the Arctic-summer program.

6.3. Comparison

Over the 10-year period, it is estimated that the difference in costs of the two alternatives would be $21.5 million or just over $2 million annually. This is a maximized cost as it would provide the capability of meeting all foreseeable demands for the next 10 years including support to year-round operation of the Northwest Passage.

7. INTER-GOVERNMENTAL AND INTER-DEPARTMENTAL CONSIDERATIONS

To date, operational interfaces for the ice information services program in the Arctic have been largely within the Ministry of Transport - the CMS with the Canadian Marine Transportation Administration and the Northern Transportation Company Limited. Components of the Canadian Air Transportation Administration provide advice to the CMS in arranging for reconnaissance aircraft and instrumentation.

Territorial and provincial governments and the Department of Indian Affairs and Northern Development are interested in ice services policy as it affects northern development, DND as it affects the conduct of military operations. The Department of Energy, Mines and Resources, Marine Sciences Branch, is engaged in Arctic ice reconnaissance in connection with the Polar Continental Shelf Project, and has many other departmental projects in ice research.

Experience in more southerly latitudes suggests a broadening of the involvement of provincial and territorial governments and of DEM&R as northern water resources are put to multiple uses. Hydro-electric, flood control, fishing, surface travel, and shipping requirements can be in conflict, and ice cover is a critical parameter often subject to some control.

This type of problem may soon arise on the Mackenzie Waterways System.

The Arctic Transportation Agency will no doubt be active in the inter-departmental and inter-governmental liaison and co-ordination work that will be essential to an orderly development of the ice services program.

8. CONCLUSIONS

Ice information services have an important part to play in the development of transportation in the north, in the provision of effective scientific services to northern residents, and in the efficient and enlightened development of Canada's northern resources.

Improvements in the ice information services require an increase in activity in both basic research and operational services. Close co-ordination of effort is essential among all of the public and private agencies in Canada that are engaged in this work. The Working Group on Ice In Navigable Waters of the Canadian Committee on Oceanography co-ordinates and encourages ice research, promotes uniformity in codes and terminology, and provides a forum for an exchange of views between the research and operational communities. However, closer co-ordination of operational programs is needed, particularly in river systems.

The CMS can best contribute to the over-all ice services in Canada by concentrating its efforts on:

(a) The acquisition, collection, analysis, prediction, and dissemination of information on the distribution and characteristics of ice floating in large bodies of water;

(b) The archiving, statistical processing, and co-ordination of data on floating ice;

(c) The provision of advice on the availability of all types of data on floating ice.

The skills and facilities of the CMS should also be used, when appropriate, for the acquisition of data on break-up, freeze-up, and thickness of ice in inland waters, and in support of ice information services in rivers.

The Ice Information Services System of the CMS should include as operational units an Ice Data Acquisition Unit, an Ice Forecast and Advisory Unit, and an Ice Climatology Unit. Emphasis within this System should be placed on the conversion from visual observations to remote sensors and on the use of remotely-sensed data, in order that the System be capable of responding effectively to the changing requirements of the 1970's.

The sophisticated instrumentation and the operational peculiarities of the ice reconnaisaance program would require exclusive use of the aircraft, as at present. A study has shown that, under such circumstances, purchase and in-house operation would be economically preferable to leasing. Capital costs for a data-acquisition system using three such aircraft (the maximum foreseeable requirement) would be about $20 millions. Annual operating costs of the total system, designed to achieve maximum value from the data-acquisition capabilities of the three aircraft, are estimated as follows (in thousands of dollars):

Aircraft operating expenses (crews, fuel, maintenance, depreciation, 1800 hours utilization per aircraft)	$3,000
CMS Ice Data Acquisition Unit (staff for aircraft, conventional icebreakers, Polar icebreakers, and program development, total staff 59)	1,000
Ice Central (a computerized real-time processing facility plus an advisory capability in Ottawa, total staff 18)	250
Ice Climatology Unit (a computerized archiving, quality control, and statistical processing unit, publishing costs, total staff 12)	175
Mission-oriented research (in-house & support of university research)	100
TOTAL	$4,525

6.3. Comparison

	Costs (in millions of 1971-72 dollars)		
Program	Capital	Operating	10-year totals
Arctic-summer	0	4.35	43.5
Year-round	20	4.5	65.0

The ten-year difference of $21.5 millions would convert the present ice information service into a modern, computer-age service capable of meeting all foreseeable demands during the next ten to fifteen years. It is emphasized again that the costs of the year-round program have been maximized. Two, rather than three, modern aircraft will be capable of meeting all requirements for ice reconnaissance until such time as the Northwest passage may be extensively used by surface ships in a year-round operation.

7. INTER-GOVERNMENTAL AND INTER-DEPARTMENTAL CONSIDERATIONS

To date, operational interfaces for the ice information services program in the Arctic have been largely within the Ministry of Transport as it is now constituted - the CMS, the Canadian Marine Transportation Administration, and Northern Transportation Company Limited. Components of the Canadian Air Transportation Administration provide advice to the CMS in arranging for reconnaissance aircraft and instrumentation.

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(c) The provision of advice on the availability of all types of data on floating ice.

The skills and facilities of the CMS should also be used, when appropriate, for the acquisition of data on break-up, freeze-up, and thickness of ice in inland waters, and in support of ice information services in rivers.

The Ice Information Services System of the CMS should include as operational units an Ice Data Acquisition Unit, an Ice Forecast and Advisory Unit, and an Ice Climatology Unit. In order to meet present needs effectively, and in order to be prepared for future development in ice-sensitive activities, the system should take immediate action to:

(a) Arrange for aerial reconnaissance capabilities adequate to meet expanding "normal" requirements in the 1970's;

(b) Convert the Ice Data Acquisition Unit from visual techniques to remote sensors;

(c) Develop the skills and techniques needed to make optimum use of remotely-sensed data in the Ice Forecast and Advisory Unit and in the Ice Climatology Unit.

TERMINAL FACILITIES IN THE ARCTIC

BY: CAPT. J.B. GARVIE
FEDERAL COMMERCE AND NAVIGATION COMPANY

Introduction

The only major area which the technology of marine transportation has not conquered is the Arctic. The ice has been a navigational barrier since the days of the Vikings. In recent years the ship-building industry reached and passed the 100,000 ton barrier, made believers out of all the doubters that the container ship was practical and even made Rube Goldberg blush when it gave birth to the Lash Ship, and now only the Arctic is left.

The initial voyage of the "Manhattan" signalled the beginning of the end of the numerous unknowns in Arctic transportation. Although the Arctic has not reached the development stage where formal terminal facilities are required, or, in fact, needed, the day will soon arrive when careful planning of the installation is imperative. The future Arctic supertankers, ore carriers, cargo vessels will demand not only new ports and harbours to accommodate them, but also much more efficient loading and unloading facilities than we experience in temperate climates as port time is precious in any trade, but in the Arctic it is a luxury.

A brief examination of the various factors which dictate the progress of development of a port and its terminal and dock facilities will require a most detailed study. It has been established by numerous people that irrational development in permafrost regions can have a profound effect on the environment. Any major construction project will require a careful assessment of the ecological balance, and this control must be initiated in the design stage and followed through until completion.

This study will include some or all of the following:

2) The economic development of the hinterland and the volume and type of through-put cargo.

b) The transportation connections (road or pipeline) to the hinterland and the access to the open sea.

c) Cargo characteristics, type of handling equipment, and consequently the type of vessel required for these commodities.

d) Storage requirements for the incoming consumable and durable goods, and the storage facilities for the outgoing cargo.

3) Foundations, structural and hydraulic requirements and the conditions under which the facility will function.

f) The ownership of the port facilities, responsibilities for operations, and the administrative and management responsibilities of the port.

g) In Arctic navigation, patience is mandatory. All too frequently industry becomes too impatient and locates installations in the wrong area. The terminal must go as close as possible to the product, not the product to the terminal.

In the following outline, which will be extremely brief for a very complex requirement, it is hoped that information of some value may be transferred.

Type of Terminal

I am convinced that the initial permanent terminal in the Arctic will be an adaptation of the conventional terminal facilities found in most ports in the temperate climate. The risks are too great and the initial cost too excessive to embark on an experimental operation at the outset, and whether it be an import facility or an oil or mineral loading terminal the first installation will be engineered on the basis of known factors rather than untried projects. When trained personnel becomes acclimated to the unfriendly Arctic conditions a departure into the unknown can be considered. Ice islands, submarine habitat and underground cells have all been researched by computers and "black boxes", and some practical application of these operational innovations may be realized in the future, but unless some company or Government Department is blessed with an excessive amount of capital, a major departure from the "norm" should not be considered.

The treatment of the permafrost will be the foremost consideration in the development of the terminal - each report on permafrost research indicates that man has over-researched permafrost and nothing more can be learned, and then the next report discovers some-

thing new and the foregoing statement is reiterated - in any event regardless of whether the basic structure be of steel sheet piling or cement piling, or whether the design be of batter beam, rods or cellular, the treatment of the permafrost must be the first consideration and the terminal be designed to accommodate the type of permafrost in the surrounding area.

During the transition period from the nomadic to the permanent terminal Resolute will continue to be the major transfer base in the Eastern Arctic. We believe that Resolute Bay, which has been considered temporary for the last 10 years, could now be classified as a permanent installation and that inexpensive dock and shed facilities could be constructed without disturbing the Department of Transport's budget. The dock facilities could be constructed in such a manner and in such a location to facilitate the berthing of cargo vessels. It should also be noted, as we live in an age in which pollution and the corrective measures to this pollution are paramount in the minds of all people, any expansion in the Arctic should be controlled, and this control can be better served if the shipping lanes were confined to one particular route to one area which offers a transfer station for the cargo. Resolute is the only available harbour suitable to furnish the oil and mining industry with the necessary facilities, and we suggest that the Government offer meaningful assistance to the ocean transportation industry by improving the shore line facilities to the same extent as offered to the air transportation industry.

Definitions

In the classical sense a terminal facility, when referring to a seagoing operation, are those facilities used to berth ships, receive and deliver cargo to vessels, to transship some items of cargo and deliver others to consignees, and, in general, to complete and account for the inland disposition of the cargo, thus terminating the carrier's contract of transportation. In a number of cases, for the sake of convenience, a terminal operator may act as the bailee of the goods, and we see that this function may become a necessity in the Arctic to accomplish an overall reduction in the abnormal cost factors.

Throughout the ocean transportation world the ownership of terminals is mainly public corporations such as Port Authorities, Port Commissions, Harbour Boards, etc., and the actual facilities are either operated by the port, or a commission for the port, or are

leased to shipping companies or private terminal operators. Some terminals are privately owned and operated but are available for public use, but in most cases these terminals are built for a specific trade or to perform a specific function for a particular type of cargo. In the Arctic it may be practical for terminals which handle only bulk commodities such as ore concentrates to be privately owned and operated, however, a terminal which is designed for the handling of material, supplies, and consumable goods for consumption in the Arctic will certainly require financial assistance and operating expertise from Government Departments.

Location

At the present time terminal facilities in the Arctic, by necessity, are nomadic in nature and mobile or temporary in construction. The geologists will eventually tell us when and where to build - it has been my experience that, as a group, geologists are the original optimists, but if they are remotely close to being correct in their optimism, the Canadian Arctic will experience a prolonged period of active exploration for oil and minerals. After the geologists have presented their wares, and the initial probe is undertaken, if the results are encouraging, a logistic problem of monumental proportions is presented.

Not only is it necessary to transport a horrendous grocery list through an unfriendly ice canopy to a location, which, in all probability, has not been adequately charted, but also to discharge, arrange/construct a storage area, and to move the cargo inland where the scene of activity is located. Somewhere in this sequence of planning a temporary terminal facility must be considered. The relative location of this facility will be determined not on the principals of economics but on pure necessity.

The site of any permanent terminal in the Arctic will naturally depend upon the location of the major producing area, but the important factors for the final selection within the perimeter of this site will depend largely on the following:

1) The characteristics and history of the spring breakup and the frequency and force of the prevailing winds after breakup.

2) The depth, texture and type of permafrost.

3) The tidal range and velocity of currents, and the magnitude of the wave action.

4) The availability of useable silt or gravel on the adjacent uplands, on the beach, and under the adjacent water, and whether the underwater characteristics of the proposed harbour contain a deposit coverage which can be utilized.

5) The maximum number of ice free or navigable days which can accommodate the present ice strengthened vessels.

6) The extent of level ground in the adjacent hinterland which can accommodate an all weather airstrip capable of handling Hercules aircraft.

In the western Arctic there are a number of locations where the foregoing requirements are fulfilled, but this area has a built-in restriction which limits the location of a transfer terminal to the area in and around the Arctic coast at the mouth of the Mackenzie River System, or at the northern terminus of the often proposed all-weather road through the Yukon. Until such time as technology has presented the mariner with ways and means of overcoming the hazardous trip through the polar ice off Pt. Barrow the flow of cargo to the western Arctic will be confined to the Mackenzie River System.

As you are all aware, Herschel Island attracted considerable attention during and after the "Manhattan" romance. The feasibility of an operative terminal was confirmed (at a high cost) but the fact that the "Manhattan" failed to prove that the Northwest Passage was a safe economical route subordinated the Herschel Island status to the realm of academics.

The eastern Arctic presents a much more complex problem in that the likelihood of discovering a marketable commodity within easy access to the southern markets is extremely remote. Our company discharged about 10,000 tons of cargo in a location in Bathurst Island which has all the ingredients and the potential of being an ideal harbour. This location can easily facilitate a cellular type of dock installation, has extremely deep water, is sheltered from the ice, and has an operative Herc. strip. The most important ingredient is missing - no product.

It seems fairly obvious that nature will not assist man in exploiting her resources, consequently it is most likely that any major oil discovery in the Arctic will be located in an area which will present the most difficulties in extracting the produce from the source.

This will then require higher costs and more detailed planning to construct a terminal which will be adequate to satisfy this major producing instrument. The most difficult area available for transportation of oil is obviously the east coast of Ellsmere and Devon Islands and we can rest assured that this will be the area where man will be required to construct such a terminal.

Labour Requirements

The problem of securing a good labour force exists in all areas where terminals are in operation. The most exotic equipment and the most modern machinery cannot be utilized unless an experienced and well adjusted labour force is available - we operate three terminals which have an annual throughput of over one and a half million tons of general cargo which cannot be containerized, and it has been our experience that it requires at least one year to train a totally reliable labour force capable of handling and caring for valuable units of mobile machinery and cranes.

Not only will similar problems be experienced in the high Arctic but also the major obstacle, that of adjusting labour to the cold, and also continual darkness, will magnify the problem of operating an efficient terminal. Within our company we have individuals in the supervisory level who have directed labour in many countries throughout the world. These labour forces include union and non-union, experienced and sometimes totally inexperienced, also include black, red and white-skinned people. We, therefore, believe that we are adequately equipped to comment on the Estkimo as a potential labour force in any Arctic expansion. Contrary to the popular opinion the Eskimo is a reliable employee. The Eskimo can adapt very quickly to new methods and under different conditions. The Eskimo can handle equipment with care, and are cognizant of the results of mistreatment, and we have also found that the Edkimo is totally receptive to fair treatment.

A terminal cannot be successfully operated by absentee management or supervision, and this is particularly so in the Arctic. We have found

that there is ample talent within the Eskimo community to supplement and eventually administer a terminal, and this includes every phase of the operation. It is, therefore, from the Eskimo source that the skilled labour and technicians must be found to successfully operate an Arctic terminal.

Conclusion

It is essential that an Arctic terminal be constructed and operated by organizations who have gained Arctic experience by the principals of osmosis.

Unfortunately there are no schools or institutions which can adequately train or advise or direct people and companies to adjust their operational methods to the severe climatic conditions found throughout the Arctic. We all realize that the Arctic ecological balance is extremely delicate and that man in his haste to succeed will sacrifice Nature's contributions, but if we are to remain in the Arctic, any installation, whether permanent or temporary, must be constructed within strict guide lines instituted and enforced by a Government Department.

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ICE INFORMATION, MARINE NAVIGATION, AIDS AND TERMINAL FACILITIES

BY: CMDRE. O.C.S. ROBERTSON
NORTHERN ASSOCIATES LIMITED

A first requirement in approaching any subject is to define it. Just what do we mean by the word "Arctic", that region of our planet which lies under the constellation of "ARKTOS", the Land of the Bear? I would suggest that "Arctic", when applied to Marine Transportation, should embrace those waters where navigation is impeded or restrained by the presence of ice.

Under this definition, all Canadian waters and the approaches to them, with the single exception of our Pacific seaboard, would be Arctic waters for at least some part of each year.

The attached chart shows the areas surrounding the Canadian Coast or guarding the approaches, which are ice infested, and the following table gives the approximate dates when ice formations appear and when open water can be expected for each of these areas.

AREAS AND DATES ICE FORMATION BEGINS AND DATES OF OPEN WATER.

AREA		ICE FORMATION BEGINS	OPEN WATER
Great Lakes		12 Dec.	20 April
Area	1	25 - 30 Dec.	14 May
	2	20 - 25 Dec.	14 May
	3	15 Dec.	11 June
	4	20 - 25 Dec.	11 June
	5	15 Dec.	9 April
	6	1 Dec.	9 July
	7	20 Nov.	23 July
	8	1 Nov.	20 Aug.
	9	15 Nov.	10 Aug.
	10	15 Oct.	10 Aug.
	11	15 - 20 Nov.	15 Aug.
	12	15 - 20 Nov.	5 - 10 Aug.
	13	5 - 10 Nov.	15 - 20 Aug.
	14	20 - 25 Oct.	5 - 10 Aug.
	15	1 - 5 Oct.	1 Oct. Variable.
	16	10 Oct. Western Part. 5 Nov. Eastern Part.	5 Sept.
	17	15 Oct.	30 Aug.
	18	1 Oct.	10 Aug.
	19	1 - 5 Sept.	Does not occur.
	20	10 - 15 Sept.	Does not occur.
	21	20 - 30 Sept.	10 Sept. Western Part. 10 Aug. Eastern Part.
	22	25 - 30 Sept.	Does not occur

Area	23	5 - 10 Sept.	Does not occur.
	24	1 - 10 Sept.	Does not occur.
	25	1 - 5 Oct. Eastern Part.	10 Aug.
		10 - 15 Oct. Western Part.	20 Aug. Variable.
	26	25 Sept.	5 Aug. Variable.
	27	20 Oct.	20 July
	28	10 Nov.	15 June
	29	20 Dec.	20 May

While this Conference is mainly concerned with transportation into and through our waters which lie north of the 60th parallel of latitude, the requirements for navigation in these high latitudes should also be the requirements for navigation where similar environmental restraints, in the form of ice, exist.

The carriage of goods into, out of and through any waters which are ice infested is, at present, expensive and difficult. The nature of the terrain, the rigors of the climate, the persistance of ice, the shortened shipping season, the lack of established or adequate port facilities, are but some of the factors which affect our marine transportation system. To these we must add the high cost of insurance, the lack of adequate aids and the normal degrees of stupidity which we seem able to apply to any problem.

All Canadian waters are navigable by ship on a year round basis if we wish to pay the penalties of Additional Strengthening, Horse Power and reduced cargo capacity.

The Naval Architect and the Shipbuilder can provide such vessels, vessels capable of withstanding the ice strengths and pressures which will be experienced; vessels which can meet any regulations which can sensibly be made with regard to safety, both to themselves and the waters through which they pass, vessels suitable to navigate all these waters on a year round basis. These vessels would, in many cases, also be highly uneconomic.

The above statement is not to be construed as a damning of marine transportation in these areas; such an interpretation would be classed as a "normal stupidity". I would suggest, rather, that the above paragraph be interpreted as a statement that ships can be designed, built and navigated in compliance with the necessary safeguarding regulations and in conformity with the necessary standards for the carriage of goods into, out of and through these Arctic waters, for whatever periods the economics of the operation will support.

The state of the art is no longer the barrier. The only factors which now influence the use of these waters are, "A" The economics of the operation, and "B" The very human trait of resistance to change. Many of us would prefer to be wrong than to be recent.

Another factor which influences us is that of believing that ice is ice is ice, no matter where you find it. Unfortunately, this belief has no foundation in fact. The permissiveness of ice, like the permissiveness of a woman, depends on many factors, not the least of which are Time Period, Place, Age, Intrusions, Configuration, Strength, Power and, the Knowledge and Skill of the Aggressor.

The presently accepted periods of navigation into these waters can be greatly extended by the use of the technologies and knowledge that are presently available. The only limiting factor is the economic one.

Before commenting on the Aids and Terminal Facilities, it might be wise to look at the question, not from the point of view of "How" but from the point of view of "Why". What commodities require transportation, where are they located, where are they coming from, where are they going to, by what routes will they travel, what vehicles can carry them and what qualities must these vehicles have to transport them in an economic manner?

Referring back to the Key Chart, Areas 26, 25 and 22, the Mackenzie Delta, Amundsen Gulf, Coronation and Queen Maud Gulfs Area. Commodities requiring transport are, Oil, Gas, Minerals outbound and support supplies inbound, Oil and Gas by Surface Tankers or by Pipe Line, Oil by Submarine Tanker, Minerals by Surface Bulk Carrier, either self-propelled or tug-barge combination. The submarine cannot be used, in the foreseeable future, as a carrier of L.N.G. or Minerals, even in slurry form. Inbound support supplies by tug-barge down the Mackenzie Route.

The Queen Elizabeth Island Area. Oil, Gas and Minerals outbound and support supplies inbound. Oil, Gas and Minerals, by surface vessels and pipe line and Oil by submarine tanker. Inbound, surface vessels.

Areas 18, 17, 16, 8. The Ellesmere, Baffin Area. Mainly Minerals outbound and support supplies inbound, with carriage by surface vessels, in the main, self-propelled. The use of tug-barge in this area is only feasible over a short period.

Areas 9, 10, 11, 12, 13, 14 and 15. The Hudson Strait Route. Here we have two different requirements. The carriage outbound of the products of the extraction industries. Oil, Gas, Minerals, with the inbound support supplies for these industries, and the carriage of goods inbound and outbound destined for the Central Provinces, through the Port of Churchill. The waters of Hudson Bay and Hudson Strait will support submarine tankers for the carriage of oil, but the location of submarine terminals is limited, e.g. Chesterfield Inlet Area. All other commodities will be carried by surface ships, either self-propelled or tug-barge.

Perhaps before going on I should publicly eat crow. Up until about a year ago I have strongly opposed the concept of submarine tankers for the carriage of oil out of the Queen Elizabeth Islands or through the Northwest Passage. The depth restrictions and the constant depth keeping ability of the submarine made this mode of transportation far too risky. These adverse factors are now no longer with us. Hydrographic and oceanographic research and survey have confirmed that there are channels of over 50 fathoms in depth along most of this route. Most of our experience, experience upon which I based my opposition to the submarine transport concept, was based on the military submarine, a vehicle which, because of military requirement for speed and high manoeuverability, was particularly unfitted for navigation in the shallow waters of the Canadian Arctic. We now find that these shallow waters, while still shallow, are deeper than we had previously supposed. The configuration of the submarine itself changed when the military characteristics were no longer the overriding requirement. The bulk carrier submarine is literally a different beast. The animal we are talking about now is a monster of some 170,000 D.WT. with a length of some 900 feet, a beam of 140 feet and a depth of some 85 feet. Her lines are more consistent with those of a rather placid, slow-moving bemonster than of a fast, predatory shark.

When I say slow, I'm talking of speeds of 16 to 18 knots, not 30 knots plus, and when I talk about manoeuverability, I mean that she is more manoeuverable than a surface ship but not manoeuverable to the extent required of a military submarine. She is sailed rather than flown and a fast Williamson turn in three dimensions is beyond her capabilities. She would have a lesser power requirement than her sister on the surface, a sister who would transport the same tonnage over the same route in the same ice regime, say 75,000 SHP as opposed to double that or more.

While I am on the submarine kick, a few words on her navigational aids might be more appropriate here than later on where I talk about navigational aids for surface shipping.

As the submarine will be travelling underwater, at depths of 100 to 500 feet, she will have to use navigational methods and aids different to those used by surface craft. She will not be able to navigate either optically or by standard electromagnetic means. The present method of under ice navigation is by an inertial navigation system - very sophisticated, expensive in both initial cost and in operating and maintenance costs. This system, while it has the advantage of being internal, requiring no shore-based facilities, does depend on the submarine surfacing at least every 48 hours to obtain an azimuth bearing, gyro drift must be compensated.

The inertial navigation system is more than adequate for the ocean stretches of the voyage, but when the ship enters pilotage waters she will have to rely on an acoustic system for accurate position fixing.

The provision of underwater sound beacons, which would require power and frequent maintenance, would be difficult and expensive, especially in these latitudes. A system of underwater self-powered transponder beacons, with their long line, i.e. they only send out a signal when interrogated, and their ability to provide range and bearing, would appear to be a solution.

In addition to the instruments and transponders needed for direction and position, the submarine must have the ability to detect and thus avoid obstacles in her path, i.e. icebergs, underwater pinnacles, etc., as well as devices which will tell her not only how much water she has under her keel and how much water she has over the top of her sail, but also the thickness and geometry of the ice canopy overhead.

All the above devices are off the shelf items to-day. While the advent of this leviathan will undoubtedly result in improvements to present instrumentation and techniques, we do not have to wait for a break-through to make navigation safe.

The mix of vehicles which must be considered will now include the transport submarine.

I would now like to turn to surface ships, specifically to what is required for and by the bulk carriers, self-propelled or in the tug-barge combination. First of all the vessel must be ice worthy, i.e. she must be of such a strength that ice along the route that she is to traverse during the period of the voyage or voyages, will be of no threat to her watertight integrity. Secondly, she must have sufficient power to maintain an economic speed of advance in the face of resistance offered by the ice.

Let us here look at a hypothetical voyage of a vessel carrying a cargo of bulk turnips from Northern Baffin Island to Rotterdam. This voyage should be considered in two parts. A: The Arctic portion from Northern Baffin Island to the Labrador Sea, Latitude 60°N, Longitude 52°W, a distance of some 1200 miles, and B: the conventional portion, from the Labrador Sea to Rotterdam, a distance of approx. 2100 miles.

These distances are, of course, subject to variation because of diversions dictated by ice distribution at the time and by optimum weather routing considerations. Only 40% of the route therefore, lies within the Arctic portion of her voyage and the penalties imposed upon her in additional strengthening, horsepower and reduced cargo capacity are not required for the remaining 60% of her voyage. However, due to the reduction in speed of advance in the Arctic portion of her voyage, she could well spend in the order of 70 - 75% of her time under the special conditions attending navigation in Arctic waters. The economies of the operation would suggest that this percentage of time must be kept to a minimum, the closer it gets to the same percentage of the total distance, the better.

The alternative solution is, of course, the provision of special vehicles for the Arctic portion of the voyage and conventional vessels for the conventional portion of the voyage, but here we run into the economics of trans-shipment. Intermediate terminal costs, trans-shipment time, etc. This may be acceptable in the case of oil but turnips and some other commodities do not lend themselves easily to a trans-shipment type of operation. If, however, the length of the conventional voyage were shortened and the length of the voyage of the specialized ship increased slightly, then it might be possible to turn the trans-shipment terminal into a distribution terminal where the cargoes could be consigned to a number of ports.

The above confused me a little. Let's look at one commodity - Oil. From the Islands by specialized transportation, surface or submarine, to a distribution point such as the west coast of Greenland or even Newfoundland, then by conventional tanker to its destination.

In this case the specialized qualities of the vessel used on the Arctic portion would be used for a greater percentage of the time and over a greater percentage of the route. The conventional portion of the route would then be open to any tanker now in the world's tanker fleet. Remember too that there are very few ports which can accept the giant tanker and the economies of the giant tanker could well be less advantageous in comparison with the economies of the medium size tanker in this distribution role, and with smaller tankers the loss of a ship would not present as great a pollution hazard.

Thirdly, surface vessels must be equipped with a higher standard of navigational aids and must be supported by more sophisticated shore-based aids than are required for a conventional voyage, and lastly, it is mandatory that ships employed on these trades be manned by skilled, ice-knowledgeable people. The possession of a Master's Certificate of Competency is no passport to conducting a ship in these waters. In fact, the mere possession of such a Certificate, if the possessor has not kept abreast of new technology and methods, should not qualify a person to operate any class of vessel. I am inclined to the belief that certificates should be subject to re-examination we demand this of aircraft pilots, why not of ship masters? I have a Master's Certificate of Competency for sea-going steamships, granted in 1932, which under existing regulations allows me to command any Commonwealth ship afloat. I would doubt that my present competence would justify this, and I am no worse, and probably no better, than many of my fraternity.

NAVIGATION:

SHIPBOARD NAVIGATIONAL EQUIPMENTS.

The basic minimum outfit of shipborne navigational equipment required includes the following:

a) Two magnetic compasses. One standard and one after steering position.

b) An efficient Gyro compass.

c) Facilities for taking accurate compass bearings in all directions.

d) Radar of approved standard specifications, and facilities for plotting radar readings.

e) Radio direction finding apparatus (MFD/F), capable of taking bearings on the frequencies of Marine Radio Beacons, the radio telegraph distress frequency (2182 kHz).

f) Sounding apparatus:
   I: Echo Sounding Machine.
   II: One deep sea lead line of at least 120 fms. with a lead of at least 28 lbs. and an efficient reel.
   III: Two hand lead lines.

g) One Taffrail Type Rotating Log unit.

h) Chronometers and Sextants.

i) Charts and Navigational Publications appropriate to the waters in which the ship is to operate.

The above are the minimum requirements stipulated in the "Navigation Appliance Regulations" Section 410, Canada Shipping Act (PC 1955-1754, amended by PC 1956-1797 and PC 1964-1323); with the addition of new requirements included in the International Safety of Life at Sea Convention 1960 (SOLAS) as amended in November 1968 and October 1969. SOLAS Convention Chap. V, New Regulation 12 on Shipborne Navigational Equipment was adopted by the Maritime Safety Committee of IMCO, November 1968, and included the requirement for Radar and an Echo Sounder. This provision for Radar and an Echo Sounder are not yet required by Canadian Regulations. I would suggest that they be so required. In fact, I would go much further, I would suggest that Canadian Regulations stipulate that all ships navigating in ice infested waters be obliged to carry two radars, one 10 CM (S Band) and one 3 CM (X Band, capable of being interswitched so that both can be used simultaneously on the same radar, on same or different range scales; or each on either radar, and that, where the ship is operating in areas where first order survey charts have not yet been produced, two complete Echo Sounding Machines be also required, both of which to be of the recording type which produce a continuous graph of the bottom profile.

Over the portion of any route north of 60°N. Latitude, the paucity of conventional Aids to Navigation, the lack of overall first order survey, environmental factors, including the presence of ice in its many forms, weather conditions, long periods of darkness and high latitude, etc., superimpose additional requirements and at the same time limit the performance of many equipments.

Conventional navigational practices must sometimes be modified and augmented by special techniques. The characteristics of equipment must cater to these special requirements and give the optimum performance possible in the face of these rather hostile natural conditions.

In addition to normal navigational needs involving the elements of position, direction and distance in relation to geographical features whose position may be in doubt, the ship's movement must also be considered in relation to ice distribution.

The positional accuracy of reported ice information depends on the navigation of the ice observer and, at present, aircraft flying ice reconnaissance missions use radar, radio beacons, doppler assisted dead reckoning and Loran, where Loran coverage is available, as the means of plotting their track and determining their position. The accuracy with which they can report positions is, in general, somewhat less than is possible in ship navigation.

Inevitably there will be discrepancies resulting from the combined positional errors of the ship and of the aircraft, and also from errors in assessing ice movement between successive reconnaissance sorties. The positions of reported ice features can therefore only be regarded as approximate relative to the actual position of the ship. This means that accurate delineation for local manoeuvering must depend on the ship's own observations - visual, radar or shipborne helicopter.

It is fairly obvious then that, if economical ship transportation is to be achieved, improvements in ice reconnaissance methods and coverage are required. These improvements must include a data transmission system and a common accurate position fixing system; the ship, of course, must be equipped to make use of them.

COMPASSES:

The Magnetic Compass is of uncertain value in these latitudes. Its directive force depends entirely on the horizontal component (H) of the earth's magnetic field. As the magnetic pole is approached, this directive force diminishes and the compass becomes less and less reliable. Generally speaking, well adjusted, well sited magnetic compasses are of reduced reliability when the horizontal intensity (H) of the earth's field is diminished to 9000 gammas; erratic when (H) is down to 6000 gammas and useless as a direction finding instrument when (H) is 3000 gammas or less. (H) is about 9000 gammas in the approaches to Davis Strait and drops to about 3000 gammas in about 70°N. Latitude.

The presence of magnetic anomalies, of which there are many in these waters, further reduces the usefulness of this instrument.

The Gyro Compass serves the mariner a little better. The gravity controls which give the Gyro Compass its north-seeking properties, precessing its axis to the meridian, depends primarily on the rates of "tilt" produced by the earth's rotation. Therefore, the north-seeking properties of the Gyro are strongest at the equator and diminish with latitude until at 90° the controls have no effect. At high latitudes the effects of imperfections in the instrument and errors in its control settings are greatly magnified. However, with care in selection, adjustment and maintenance, the Gyro will give satisfactory service within the Canadian Arctic as the primary directional reference instrument for steering, taking bearings, and azimuth stabilization for the radar displays.

Most Gyros now fitted in merchant ships are not provided with facilities for making latitude settings above 70°. While tables or graphs can be prepared to show the speed and damping errors at higher latitudes which can then be allowed for in using the compass, they are inconvenient, especially because the resulting total error changes on alteration of course.

I would here suggest that our Navigating Appliance Regulations stipulate that the selected Gyro compass installations be equipped for latitude settings up to at least 75°. In view of the great dependence which will have to be placed on the Gyro, I would also recommend that adequate alternative electrical supply be provided.

Two master Gyro compasses should be mandatory, each capable of driving all Gyro bearing repeaters, steering repeaters and radar display azimuth stabilization, with the necessary change over switches.

RADAR:

On routes in more temperate latitudes the primary functions of the radar installations are to provide a means of avoiding collisions with other ships; and, in combination with other aids, to assist in the tasks of coastal navigation and pilotage. In Arctic waters, radar takes on an added importance. On the coastal portions of the route, where natural features are virtually the only land-based aids, the use of radar becomes essential and, in darkness and periods of poor visibility, can be the only aid available. In addition, radar is important for the detection of icebergs, bergy bits, growlers and for indication of sea ice features such as leads, ridges, hummocks, polynyas, etc., to help in the choosing of the least ice restrictive courses.

The problem confronting the navigator in ice is that he can rarely steer a desired course, but must make frequent alterations to make use of leads, loose ice concentrations and other weaknesses in the pack, while still keeping to the generally desired direction. These frequent diversions, sometimes involving almost continuous changes in course and speed, make it almost impossible to keep any sort of navigational plot. In ice logs must be laid in or housed; engine revolutions cannot be relied upon, as no distance or speed input is available.

With good radar and in contact with the land the answer lies in frequent up-dating of the ship's position by radar fixing, and in the use of radar clearing lines and similar "Parallel Index" techniques to ensure the ship remains within safe limits. When not in touch with the land it is often possible to determine courses and distances made good in ice by successive radar plotting of distinctive ice features.

To give optimum performance for the several purposes required under different conditions, requires a variety of radar characteristics. Long range detection of land features requires high power, long pulses and long wave length; at shorter ranges the high definition associated with short wave length, narrow horizontal beam width and short pulse is important.

In many conditions a short wave length may give the best chance of detecting bergs; while in others, sea clutter attenuation or subrefraction will dictate use of a longer wave length. Growlers, lost in the sea clutter, can be very disturbing - especially when they are on your line of advance.

Detection of vagaries in the ice pack requires a short wave length and the high resolution given by narrow beam width and short pulses. The characteristics required for optimum performance vary, depending on both function and circumstance. To provide this range of capabilities and flexibility in their use, the radar outfit must include both X Band (3 CM) and S Band (10 CM) radars.

Commercial radar sets with the required characteristics and features are available; none that I know of are, however, designed to operate under Arctic winter conditions. Provision will have to be made for special heating and drying arrangements for above deck units, as well as protection for scanner assemblies.

SOUNDERS:

The use of "Watch there Watch" or Kelvin tube sounders are unproductive in ice infested areas. Most standard Navigational Echo Sounders can, however, meet the requirement. Two such sets should be provided to ensure uninterrupted availability and it is imperative that they be operated continuously. Most of you have by now heard the story of MANHATTAN and her disregard of this elementary seamanlike precaution when navigating in unfamiliar waters.

Echo Sounder Indicators should be of the recording type which produce a continuous graph of the bottom profile, in order to appreciate bottom trends and evaluate any spurious echoes by using the recorded echograms. This is not possible when using indicators which show instantaneous depths by a flasher or a digital readout.

The transducers should be housed in inboard tanks to avoid damage by ice. It may be necessary, depending on the thickness of the shell plating, to insert thinner steel windows in way of the tanks to reduce energy losses - these tanks to be of the "sea pressure" type.

LOGS:

In ice, taffrail logs must be laid in. Bottom logs of the Chernikeeff, Pitometer or Electro Magnetic types, all employ sensor units which extend outside the hull and must be housed. Engine room revs are no longer a good indication of speed due to the varying resistance of the ice.

Much has been said of and many claims made for Doppler Sonar, the measurement of speed by doppler Shift of sonar beams reflected from the ocean floor is limited to depths of under 200 fms.; however, speed indications in the doppler mode would only be approximate and would be subject to interference and masking by ship noises which would be severe when forcing a way through ice.

The lack of any acceptable Speed/Distance measuring devices suitable for a vessel in ice or deep water, makes it even more important that the vessel be able to update her position more frequently if she is to avoid the accumulation of unacceptable errors.

ENVIRONMENTAL INTELLIGENCE:

The ship must be able to consider the general ice distribution over the whole area and its forecast movement. She must have knowledge about the ice and weather in her immediate vicinity for tactical purposes. Local diversions from the intended track are often the best means of maintaining speed of advance.

To enable timely and best available knowledge of all Meteorological factors to be used, the ship must be equipped to receive and correlate Ice and Met. broadcasts, both from the shore transmitting stations and from the Ice Reconnaissance aircraft. She must therefore be equipped with Radio Facsimile Receiver, Radio Telegraphy, Radio Telephone and VHF Radio Telephone.

The ship must also be equipped with the means of making Meteorological - including ice observations - both for her own use and for making regular ice and weather reports to shore, and so contribute to the information gathering system.

AIDS TO NAVIGATION:

Aids to Navigation can be divided into two categories. 1) Those aids which contribute to the immediate support of the ship; i.e. Ice Breaker Support, Meteorological Information, Ice Reconnaissance and Ice Reports, Lights, Buoys, Shore Based Positioning devices (Decca, Loran, Omega, etc.), Charts, Sailing Directions, etc., and, 11) Aids which contribute to the planning of the voyage, and here I would list Ice Forecasts, Meteorological Forecasts, Charts, Sailing Directions, and a comprehensive Ice Atlas showing average ice conditions along the proposed route. This latter aid to the planning phase is most important if schedules are to be maintained, cargo assembled and delivered without undue delays.

I would like to comment on these.

ICEBREAKER SUPPORT: It is obvious that close and continuous icebreaker support cannot be afforded each and every ship trading into Arctic waters - they are sophisticated and expensive vessels - and there are not - nor could there ever be - sufficient numbers of such craft to render this type of support. It is, therefore, mandatory that ships trading into these waters be capable of transiting the chosen routes independently and only rely on icebreaker support when the ice conditions encountered are far in excess of conditions which normally prevail. Trading vessels must be of such strength and have such ice worthy characteristics and be of such power that for their chosen trades, close icebreaker support is not normally required.

This does not, by any means, obviate the necessity for the provision of icebreakers. They are required to patrol the routes, to render assistance when required, as these waters deny the assistance normally available by other commercial vessels in more temperate latitudes.

The Soviet Union, on their Northern Sea Route, have adopted the practice of stationing their icebreakers at the critical points along the route - places subject to quick intrusions of sea ice or places where the ice is most likely to concentrate and build up pressure, e.g. Proliv Borisa Vil'Kilskogo. In Canadian waters this could be comparable to the entrance to Hudson Strait.

Undoubtedly there will have to be regulations as to the classification of ships which will be permitted to trade into different areas at different times of the year, i.e. their ice worthiness, and I would strongly recommend here that such regulations deal only with strength and horsepower and that they not deal with type of vessel or its configuration. In other words, they deal only with whether or not the vehicle is strong enough to resist the ice pressures normally experienced, has enough power to make her way through the ice concentrations expected and thus does not become a salvage or pollution hazard.

If regulatory authorities take unto themselves the task of specifying types of vessels - configuration and characteristics - then any advances in the design of vessels for the carriage of goods in a more economic but no less safe manner will be stifled.

I might add one more word here. At the present time we have too many dead hands on the wheel, one of them, Insurance. The requirement that vessels, to be insured, must be "in the presence of an icebreaker". We cannot afford many such unnecessary obstacles if these routes are to be opened up.

METEOROLOGICAL OBSERVATIONS AND REPORTS:

Weather Reports and Ice Reports are almost useless if they are not received within a very short space of time after the observations are made. Weather changes rapidly in these

regions and the ice is in constant movement. It is imperative, therefore, that Weather Stations and Ice Observation planes, as well as the ships, be equipped with the means of sending and receiving observations with no loss of time. Radio Facsimile equipment is a must.

ICE RECONNAISSANCE:

The main need here is for a common position fixing system and for instrumentation to achieve all weather reconnaissance - in darkness, through cloud and fog, etc. This means new aircraft with long endurance, Side Looking Radar (SLAR) and perhaps Infra Red, and an improved navigation facility such as Decca.

These sophisticated systems are available now. However, considerable study is needed NOW to determine their limitations and capabilities under the various conditions with which they will have to cope.

Ice Reconnaissance, unlike icebreaker support, is required in close support along all routes. I would say that at least daily ice recce. support is desirable, but certainly there should not be more than two day intervals between such flights on any major route.

LIGHTS:

The construction, maintenance and support of lighthouses in the Arctic is expensive, and with the advent of Radar and Electronic Positioning Systems, probably not warranted at this time. There is no doubt about the fact that the sight of a light or lighthouse can be very comforting when you are making a landfall. Sailors, being conservative by nature, like the things, but let's face it, they are becoming anachronisms in this age of electronic identification and position fixing systems, on routes that are not used by small craft which do not lend themselves to the fitting of such systems. The same comfort can be derived from a well-located Transponder Beacon or Passive Radar Reflector.

BUOYS:

"It is manifestly impossible that any reliance can be placed on buoys always maintaining their exact positions. Buoys should therefore be regarded as warnings and not as infallible navigation marks, especially when in exposed positions." Authority - Sailing Directions.

In the immediate future they may be required for narrow channels and river routes, e.g. Mackenzie Route, but they must be lifted prior to the formation of the ice and laid after the ice has cleared. This places severe limitations on the extension of the use of these routes during the freeze up and break up periods. There are, on the market to-day, electronic positioning systems such as Decca, Mini-Fix, RPS etc.,

which provide the mariner with positional accuracies required for the safe navigation of even the most tortuous channels. I recently attended trials of one such system where a Canadian Coast Guard vessel, navigating blindfolded, was able to drop two buoys, one port and one starboard, proceed for a couple of miles along the channel, then turn and split the buoys without ever having seen them.

In general, the use of lights and buoys as aids should be confined to areas where no adequate substitute system is available in a more economic form.

SHORE BASED, POSITION FIXING SYSTEMS:

There are many such systems available. Decca, Loran A and C, Hi Fix - Mini Fix, Lamda, Omega R.P.S., Satellite, Console, etc. They all have their uses under varying circumstances and conditions.

For general offshore navigation Loran C or Omega appear to hold the best promise, for coastal waters the Decca System of unmanned (automatic) stations, such as that used in the Norwegian chain, has proven itself in an unfriendly environment and given the accuracies required by ship and ice recce. aircraft and is compatible to both.

I might add that such a position fixing system is invaluable in the locating, tracking and monitoring of any oil spill. This was well demonstrated in the loss of the "IRVING WHALE" this fall. I have heard much loose talk that oil spills will be outlawed. I'm sure they will be - but they will still occur - the normal human stupidity factor being what it is, and we must, therefore, have in existence and ready to hand, the means of locating, tracking and containing them with the least disruption to the ecology.

CHARTS AND SAILING DIRECTIONS:

Until such time as our long neglect of our Arctic waters has been corrected, Charts and Sailing Directions will leave much to be desired. Here I must add that, since about 1954, the tempo of survey has been increased enormously and to-day, while they are not as detailed and accurate as we would wish, they are adequate to get on with the job of opening up Arctic navigation - I only hope that this endorsement does not become support for a "rest on your oars reversed" policy.

Peary once said that the success of any Arctic voyage is largely determined before the ship leaves her home port. A couple of other old saws are appropriate, "A little knowledge is a dangerous thing" and, "In ice infested waters the shortest distance between any two points is seldom a straight line." Of all the aids that contribute to the planning of any voyage in these waters, the one that is most important is a knowledge of the ice conditions which may be expected enroute.

This knowledge should include the following data:

The Geographic Positions through which the ship must pass.
The Average Ice Cover which has been observed.
The Maximum Ice Cover which has been observed.
The % of time when the Maximum Ice Cover was observed.
The Minimum Ice Cover which has been observed.
The % of time when the Minimum Ice Cover was observed.
The % of time when open water was observed; i.e. when ice cover was below 1/10ths.
The percentages of the various types of ice which may be present. New Ice, Young Ice, One Year Ice, Two Year Ice and Multi Year Ice. For, as you know, the age of the ice is related to its strength and therefore to the speed of advance of a ship through it. It is also desirable to know what % of the floes which may be encountered will be over 200 meters across.

Other influencing factors are:

The average number of icebergs which may be encountered. By icebergs I also include bergy bits, floe-bergs, ice islands and growlers and the number and orientation of ridges, hummocks and bummocks which may be met per mile of distance traversed.
In coastal waters, the boundaries of the land fast ice, the location of shore leads and polynyas is relevant, as is the location and boundaries of the various permanent and semi-permanent anomalies. The direction and force of the prevailing winds, the temperatures and the hours of daylight.

On the attached Chart I have shown one area in about the middle of Baffin Bay and a format sheet showing some of the ice data between 70°N and 73°N, in Area 17 for the week of 21 to 28 May. From this Chart and with this data, you can see that the preferred route between those two latitudes for that week of the year would be through Sections 1 and 2, 9 and 10 and 19. I would also, if I were planning such a voyage, be interested in the fact that, for that particular week, my ship could expect the following climatic conditions:

A Mean Maximum Temperature of 35°.
A Mean Minimum Temperature of 21°.
Probably one day of fog.
An average cloud cover of 6/10ths.
A Mean precipitation of about 0.12", with precipitation taking place on two days.
That the winds I might expect would be N.ly. 19%; N.E. 7%; E. 12%; S.E. 8%; S. 10%; S.W. 4%; W. 6%; N.W. 27% and Calms 7%, of the time. I'd be very pleased to learn that only one gale has been reported in this area for this period in the last ten years, and while it reached force 8-9, it only lasted for six hours. I'd also be glad to know that the ice has reached its maximum thickness of about 63" and has been losing its strength for the last month, and that this erosion will be assisted by 24 hours of daylight,

especially as the ship will be passing a fairly steady stream of icebergs moving northward out of Disko Bay and southward off the Baffin Coast. Ridging in the area is not excessive.

This information is not all I would like to have but it is better than nothing. I only wish we knew a little more about the dynamics of the ice, its strength and the pressures it can exert.

Besides this basic data the planner must have access to the Meteorological forecasts, including the Ice Forecasts, in order to take advantage of any departures from the mean which may be exploited to his advantage and lessen, as much as possible, the effects of worsening conditions.

TERMINALS:

The design and construction of terminals is very much outside my fields of competence. I'm just one of the poor fish head sailors who is expected to put a ship alongside and take her away again without damage, even though the designer has so arranged the geometry of the wharf or pier so that it is at right angles to the prevailing wind or fetch of sea and/or adjacent to the outpourings of a glacier, and/or a location subject to abnormal ice concentrations, and/or subject to the other hazards that disregard of nature can and does produce.

Without getting into specifics, would it be too much to ask that, as such terminals are designed, the engineers remember that they are primarily for the loading or discharge of ships and that, before the ships can commence loading or discharging, they have to come alongside. Time lost carrying out this evolution, like the time alongside, does not make for a profitable voyage.

It might be a good idea to examine the need for an Air-Marine Terminal on Banks or Victoria Islands, in the vicinity of the Princess Royal Islands.

This terminal would be served by the present tug-barge system of the Mackenzie River with its lower transportation costs and with onward transportation by air to the Queen Elizabeth Islands. The use of such a terminal would certainly reduce the total cost of transportation to the islands.

Marine and Air Navigation north of 60° is achieved at present in a variety of ways, running from the "Hark One Eyeball"/ Seat of the Pants techniques, to the use of sophisticated electronic equipment, privately operated aids and contracted positioning facilities for specific surveys.

If the Canadian Government intends to exercise control over its Arctic waters - and this is obviously its intention - then it would be desirable to enunciate as clearly as possible and as soon as possible, what the rules of the game are going to

be, otherwise it will be extremely difficult to insist that regulations be complied with without exception. It should be made quite clear that there will be no "Grandfather Rights". The transportation industry is poised to dive into these waters and somebody is going to fall off the springboard if the starting gun is much longer delayed.

The Arctic Pollution Prevention Act (Bill C.202) was given a rousing show of patriotic hands in April of this year, but to date there has been little information as to the Regulations and Standards required to support this Bill.

I'd like to stick my neck out and suggest a few of the matters that should, in my opinion, be required.

No ships or watercraft should be permitted to use Canadian waters unless their onboard navigational equipment is adequate for the intended voyage, and earlier in this paper I have suggested what instrumentation I would consider adequate.

The Government should now institute a program to provide a continuous common reference navigation system to a specified accuracy for all transportation systems, seaborne, airborne and landborne, and that this navigation system be sufficiently accurate to meet the continuing demand for a positioning system which will satisfy the exploration industry in their particular investigations, for there is no doubt but that the ultimate success of any exploration and development program in any latitude is dependent upon the ability of the exploration and transport vehicle to accurately position and relocate themselves upon predetermined points on the earth's surface.

There are to-day, off the shelf systems, which will satisfy both of these requirements. The provision of several such systems, all different, would be an unwarranted additional burden on the economic development of the area.

I would also suggest that the vessels and watercraft using these waters be of such an ice classification that they will not require, in the normal course of their operations, the continual assistance of icebreakers. I would further recommend that the existing navigation season for "tired old iron" be further restricted, to the point where vessels with no ice classification are restricted in their voyaging to areas and periods where no ice will be encountered. To my mind, this is the only method by which we can encourage the design and construction of vessels which would be capable of extending the present navigation season.

To be blunt, we have little hope of encouraging an efficient and economic marine transportation system into and out of our northern waters which will not be a pollution hazard until such time as we make it uneconomic for unworthy ships to engage in these trades.

Denial of the right of entry while ice is present will have a sobering influence. Ice is no respecter of the unfit, and if these marginally equipped and non-worthy ships are allowed to continue operations, then we are asking for trouble. Trouble, not only in the rise in the cost of insurance and loss of shipping confidence in the route, but trouble in the pollution of these waters, and I can assure you that pollution is just as much an invasion of sovereignty as the presence of a foreign man of war.

There is an old saying amongst the Greek ship-owning fraternity. "The collision or grounding or loss of a ship and its cargo can spoil your whole day." We can, by wise regulation, avoid spoiling their day.

One of our main routes into our Arctic Treasure House is the Mackenzie River Route, but if this route, both for north-bound and southbound cargo, is to be realized, we must take steps now to allow it to carry the cargoes which must be transported, otherwise, alternative routes and methods will be found and they may well be of such nature that they are, to a great extent, outside our jurisdiction. I might give as an example here, the transport of pipe and supplies necessary for the construction of a gas pipe line from the Mackenzie Delta, and, eventually, the movement of concentrates from the north to the head of steel.

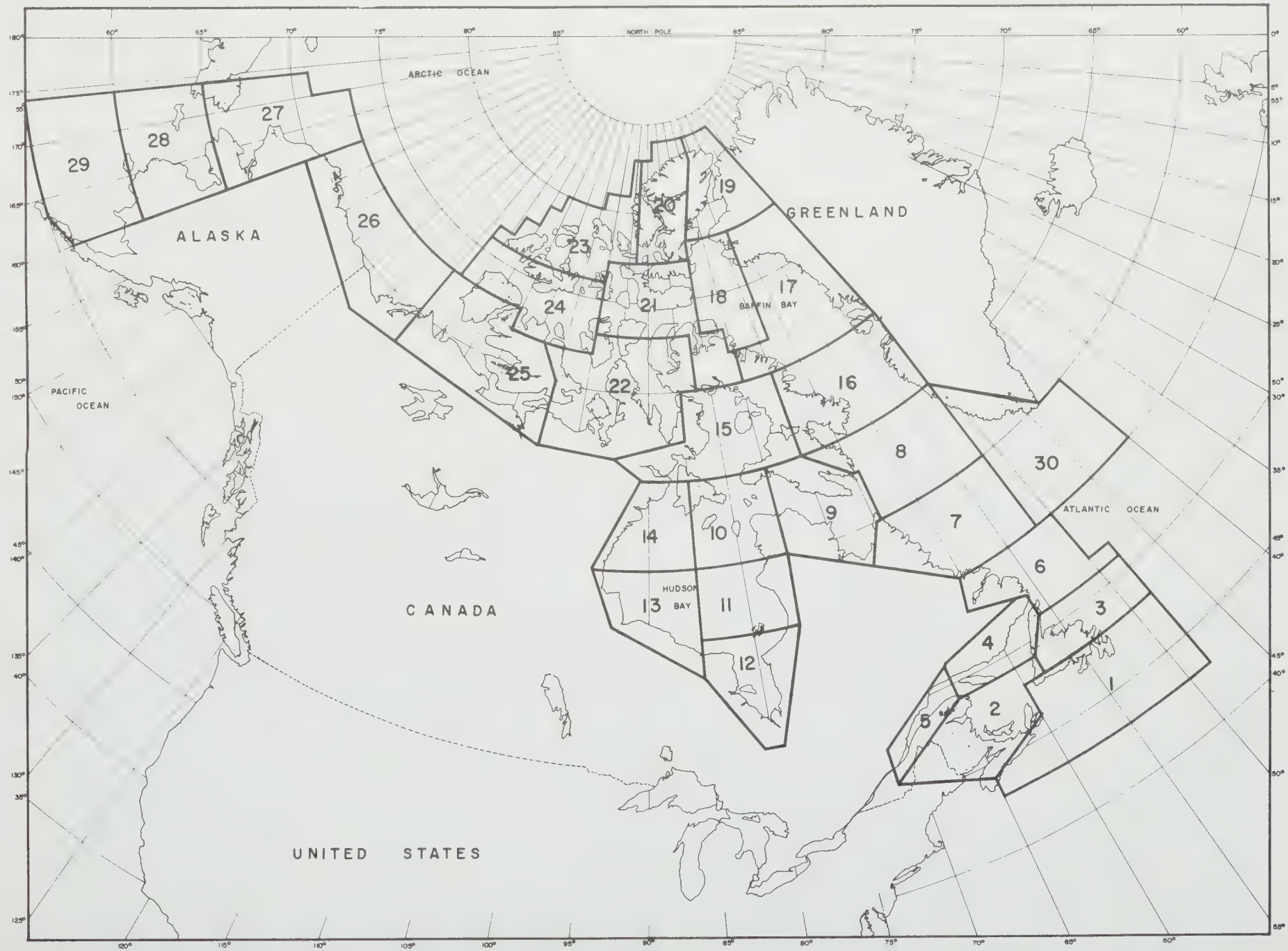
I would suggest that one of the first steps to be taken would be the setting up of a Mackenzie River Route Authority; much along the lines of our St. Lawrence Ship Channel Authority - a very efficient outfit, with jurisdiction over Navigation, Navigational Aids, Communications, Channel Depths, etc. etc., and, I would recommend to this Authority an examination of the use of barrages in addition to dredging as a means of providing maximum depth.

Another major route will be the route into the Queen Elizabeth Islands, terminating within the islands themselves or at a port on the east or south coast of Ellesmere Island. If transportation over this route is to be realized we will require a major hydrographic and oceanographic effort, and this effort will entail the provision of major icebreakers of a class far superior to the icebreakers we now possess.

Our most important existing route is the Hudson Bay Route, and if we wish to exploit its potential then we must expand the present shipping season and the key to this expansion depends on the ability of shipping to make early entry and late exit through the eastern entrance of Hudson Strait. This very small area, about half of Area 9 and less than a third of Area 8 on the key map, is the linch-pin - once we loosen this linch-pin the rest of the job is a lead pipe cinch. One of the tools required is, again, the continuous provision of several large icebreakers - we have such vessels in our existing fleet.

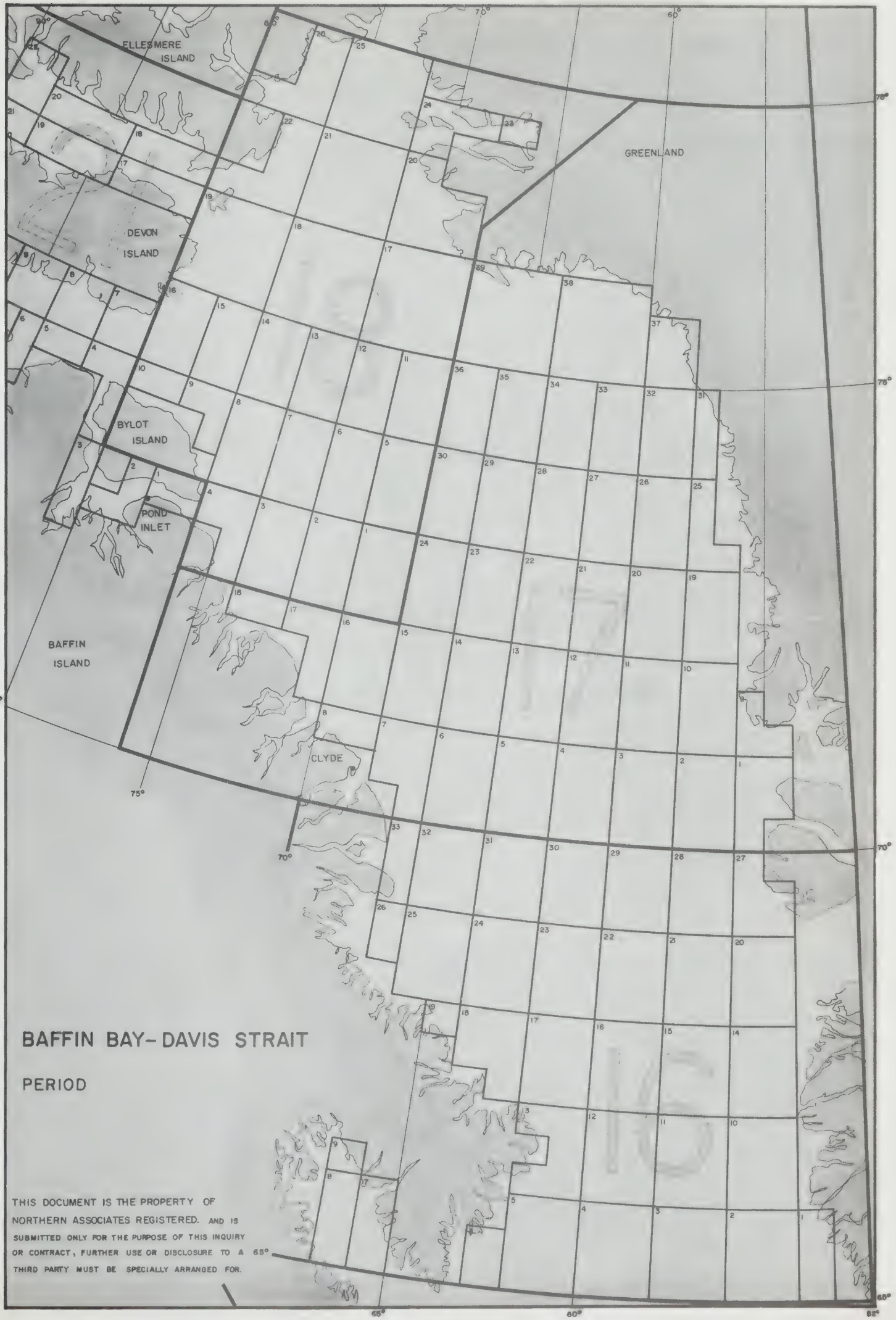
ICE DATA SHEET PERIOD 21 to 28 May AVERAGE NUMBER OF CONSECUTIVE YEARS OBSERVATIONS 5-7

AREA NO. 17 / SECTION NO.	AVERAGE ICE COVER 10THS	MAX. ICE COVER 10THS	% OF TIME MAX. COVER OBSERVED	MIN. ICE COVER 10THS	% OF TIME MIN. COVER OBSERVED	% OF TIME ICE COVER BELOW 1/10	% NEW ICE	% YOUNG ICE	% ONE YEAR ICE	% TWO YEAR ICE	% OF MULTI YEAR ICE	% OF FLOES OVER 200 M.	REMARKS
1	3	~~9+~~	30	0	50	70	-	-	100				Shore lead is common
2	5	~~9+~~	40	1	40	-	-	-	100			75	
3	9	~~9+~~	50	6	25	-	-	-	100	-	-	80	
4	~~9+~~	~~9+~~	100	-	-	-	-	-	100	0	0	-	
5	9	~~9+~~	65	8	35	-	-	5	95	-	-	80	
6	9	10	25	8	25	-	-	5	95	-	-	90	
7	9	~~9+~~	65	7	25	-	-	-	100	-	-	100	
8	~~9+~~	10	70	~~9+~~	30	-	-	-	100	-	-	100	Early data 1 yr.5/10,1 yr.open
9	4	8	25	0	25	50	0	0	100	-	-	-	
10	6	9	25	3	30	-	-	-	100	-	-	25	Early data 1 yr. open.
11	9	~~9+~~	30	7	30	-	-	-	100	-	-	25	
12	9	~~9+~~	30	7	30	-	-	-	100	-	-	25	
13	9	~~9+~~	50	9	50	-	-	-	100	-	-	-	
14	9	~~9+~~	50	9	50	-	-	-	100	-	-	-	
15	9	~~9+~~	50	9	50	-	-	-	100	0	0	-	
16	9	~~9+~~	50	8	25	-	-	-	100	-	-	90	
17	~~9+~~	~~9+~~	60	9	30	-	-	-	100	-	-	90	Early data 1 yr. 5/10ths.
18	~~9+~~	~~9+~~	75	9	25	-	-	60	40	-	-	85	
19	5	9	20	2	20	-	-	-	100	-	-	50	Early data 1 yr. open.
20	8	~~9+~~	30	5	30	-	-	-	100	-	-	50	
21	8	~~9+~~	30	7	30	-	-	-	100	-	-	60	
22	9	~~9+~~	50	9	50	-	-	-	100	-	-	-	Early data 3 yrs. 8/10ths.
23	9	~~9+~~	50	9	50	-	-	-	100	-	-	-	Early data 4 yrs. 8/10ths.
24	~~9+~~	~~9+~~	60	9	30	-	-	5	95	-	-	95	Early data 4 yrs. 8/10ths.



PRINCIPLE CLIMATOLOGICAL REGIONS FOR ARCTIC STUDIES

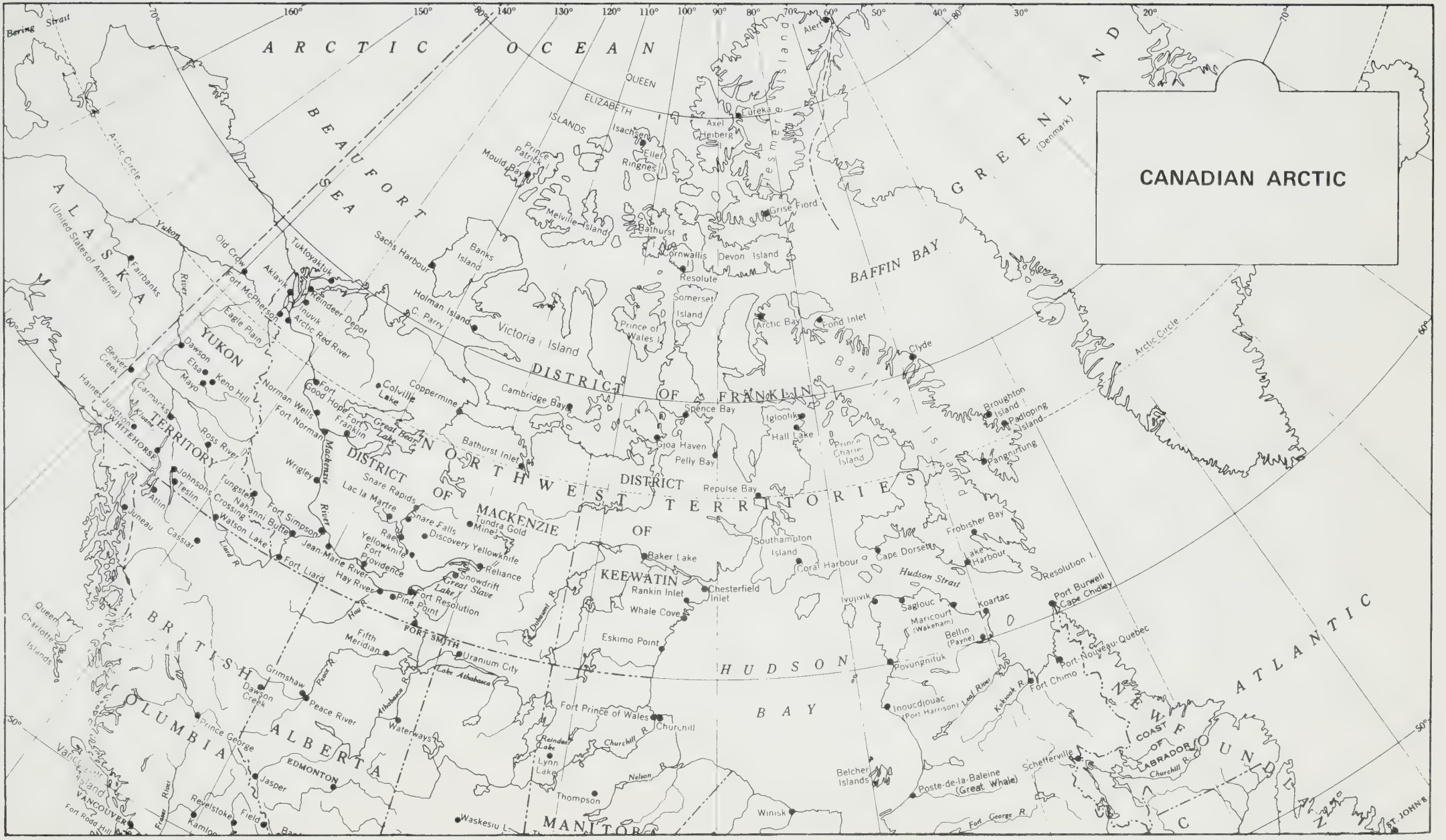
FIGURE - 2



BAFFIN BAY- DAVIS STRAIT

PERIOD

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CANADIAN ARCTIC
ARCTIC OCEAN
BEAUFORT SEA
BAFFIN BAY
GREENLAND (Denmark)
HUDSON BAY
ATLANTIC OCEAN
ALASKA (United States of America)
YUKON TERRITORY
DISTRICT OF MACKENZIE
NORTHWEST TERRITORIES
DISTRICT OF FRANKLIN
DISTRICT OF KEEWATIN
BRITISH COLUMBIA
ALBERTA
MANITOBA
ONTARIO
QUEBEC
NEWFOUNDLAND
LABRADOR
QUEEN ELIZABETH ISLANDS
Ellesmere Island
Victoria Island
Banks Island
Melville Island
Prince of Wales I.
Somerset Island
Devon Island
Cornwallis
Bathurst
Baffin Island
Southampton Island
Prince Charles Island
Coppermine
Cambridge Bay
Spence Bay
Igloolik
Hall Lake
Repulse Bay
Pelly Bay
Bathurst Inlet
Baker Lake
Chesterfield Inlet
Rankin Inlet
Whale Cove
Eskimo Point
Arctic Bay
Pond Inlet
Clyde
Broughton Island
Pangnirtung
Frobisher Bay
Cape Dorset
Coral Harbour
Resolute
Inuvik
Aklavik
Tuktoyaktuk
Old Crow
Fort McPherson
Sachs Harbour
Holman Island
Reindeer Depot
Arctic Red River
Eagle Plain
Dawson
Mayo
Keno Hill
Elsa
Beaver Creek
Fairbanks
Haines Junction
Carmacks
Klukshu
WHITEHORSE
Ross River
Atlin
Teslin
Johnsons Crossing
Watson Lake
Juneau
Cassiar
Fort Norman
Norman Wells
Fort Good Hope
Fort Franklin
Great Bear Lake
Colville Lake
Wrigley
Fort Simpson
Nahanni Butte
Tungsten
Lac la Martre
Snare Rapids
Snare Falls
Tundra Gold Mines
Discovery
Yellowknife
Fort Providence
Rae
Reliance
Snowdrift
Great Slave Lake
Fort Resolution
Pine Point
Hay River
Fort Liard
Jean-Marie River
Mackenzie River
Liard R.
Dubawnt R.
Thelon R.
Kazan R.
Back R.
Ivujivik
Salluit
Koartac
Maricourt (Wakeham)
Bellin (Payne)
Povungnituk
Inoucdjouac (Port Harrison)
Leaf River
Kakiak R.
Fort Chimo
Port Burwell
Cape Chidley
Resolution I.
Lake Harbour
Port Nouveau-Quebec
Hudson Strait
Belcher Islands
Schefferville
Churchill R.
Poste-de-la-Baleine (Great Whale)
Fort George R.
Winisk
Waskesiu L.
Thompson
Nelson
Lynn Lake
Reindeer Lake
Churchill
Fort Prince of Wales
Waterways
Athabasca R.
Lake Athabasca
Uranium City
Fifth Meridian
FORT SMITH
Grimshaw
Dawson Creek
Peace River
Peace R.
Prince George
Jasper
EDMONTON
Revelstoke
Field
Kamloops
Fraser River
VANCOUVER
Fort Rodd Hill
Vancouver Island
Queen Charlotte Islands
Arctic Circle
Bering Strait
Yukon River
Mackenzie River
Alert
Eureka
Isachsen
Ellef Ringnes I.
Axel Heiberg I.
Grise Fiord
Mould Bay
Prince Patrick
St. John's
160°
150°
140°
130°
120°
110°
100°
90°
80°
70°
60°
50°
40°
30°
20°
70°
60°
50°



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